PROCEEDINGS

of the

American Society

for

Horticultural Science

for

1932

Volume 29

TWENTY-NINTH ANNUAL MEETING

HENRY A. JONES

PROCEEDINGS

OF THE

AMERICAN SOCIETY

FOR

HORTICULTURAL SCIENCE

FOR

1932

Twenty-Ninth Annual Meeting

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Vice-Presidents.................J. R. Magness, Paul Work, Alex Laurie
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Roy Magruder (1937)

CONSTITUTION*

ARTICLE I

The name of this Association shall be the American Society for Horticultural Science.

ARTICLE II

The object of the Society shall be to promote the Science of Horticulture.

ARTICLE III

Any person who has a baccalaureate degree and holds an official position in an agricultural college, experiment station, or federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee.

ARTICLE IV

Meetings shall be held annually at such time and place as may be designated by the Executive Committee, unless otherwise ordered by the Society.

ARTICLE V

The officers shall consist of a President, three Vice-Presidents, and a Secretary-Treasurer, who, together with the chairmen of the standing committees, shall constitute a Council to act upon all applications for membership. There shall also be an Assistant Secretary. These officers shall be elected annually by ballot.

ARTICLE VI

This Constitution may be amended by a two-thirds vote of the Society at any regular meeting, notice of such amendment having been read at the last regular meeting.

BY-LAWS

SECTION 1. The President and other officers shall perform the usual duties of their respective offices. The President shall also deliver an address at each regular meeting

SEC. 2. There shall be a Committee on Nominations consisting of five (5) members, who shall be nominated and elected by ballot at each regular meeting of the Society. It shall be the duty of this Committee, at the following meeting, to suggest to the Society nominees for the various committees, and one nominee for each of the offices for the ensuing year.

SEC. 3. There shall be an Executive Committee, consisting of three (3) members and the President and the Secretary, ex-officio. This committee shall perform the usual duties devolving upon such committee.

SEC. 4. The committee on Nominations shall nominate referees and alternates upon special subjects of investigation or instruction, which may be referred to its consideration by the Society. The duties of these referees shall be to make concise reports upon recent investigations or methods of teaching in the subjects assigned them and to report the present status of the same.

SEC. 5. There shall be a Committee on Program, consisting of three (3) members, of which the Secretary shall be one. This committee shall have charge of the scientific activities of the Society, except as otherwise ordered by the Society.

SEC. 6. The annual dues of the Society shall be four dollars.

SEC. 7. Ten members of the Society shall constitute a quorum.

*The Constitution and By-Laws as amended from time to time.

SOCIETY AFFAIRS

RESUME OF THE ANNUAL MEETING AT ATLANTIC CITY, NEW JERSEY, DECEMBER 28, 29, AND 30, 1932

The twenty-ninth annual meeting was held at the Chalfonte-Haddon-Hall Hotel, which was also the Society headquarters. Although attendance was affected by general financial conditions throughout the country, yet the sessions were interesting and the discussions were helpful. There were 163 papers on the program, the largest number in the history of the Society. The meetings were run promptly, according to schedule. There is a noticeable improvement in the conciseness and the clarity of presentation as compared to the meetings a few years ago. There were 14 sections held during the 3 days, including a joint session with the American Society of Plant Physiologists.

The dinner and social evening was held at the Chalfonte-Haddon-Hall Hotel with 114 present.

REPORT OF THE EXECUTIVE COMMITTEE AS ADOPTED

1. It is recommended that the editorial committee be authorized to insist upon considerable change in context and reduction in length of manuscripts if in its opinion this is desirable.

2. If three members of the editorial committee are of the opinion that any paper is not suitable for publication, it need not be accepted.

3. After being edited by the editorial committee, papers shall be sent to authors for their action, after which, each author will return his paper to the member of the committee who edited it.

4. Except for the Presidential address, each author will be permitted four printed pages, exclusive of cuts and plates, without printing cost to him. All printing in excess of these four pages will be borne by the author. As at present, each author will pay for zinc etchings and copper cuts. In case of joint authorship, the senior author is responsible for the context of the paper and for all cost of printing above his individual allotment of four pages.

5. The sponsoring of papers of non-members will be discontinued.

CHANGES IN THE SOCIETY CONSTITUTION AND BY-LAWS

The amendment to Article III under the heading "Voting Members" was carried, namely:

> "Voting Members—Any person who has a baccalaureate degree and holds an official position in a university, college, experiment station, or Federal or state department of agriculture in the United States or Canada, is eligible to membership. Other applicants may be admitted by vote of the executive committee."

The part under the heading "Non-voting Members" was rejected, namely:

> "Non-Voting Members—Any person holding a baccalaureate degree shall be eligible to membership in this class."

The amendment to Article V providing for three Vice-Presidents was carried, as follows:

> "That Article V be amended to read: The officers shall consist of a President, three Vice-Presidents, ..."

PROPOSED CONSTITUTIONAL AMENDMENTS

The following amendments were proposed, to be voted on at the 1933 annual meeting:

1. Amendment to Article III concerning associate members:

Associate Members: Any person not eligible to voting membership will be eligible to associate membership upon vote of the executive committee. Associate members shall not vote and will present papers only at the request of the program committee.

2. Amendment to Article V concerning the election of officers by mail instead of at the annual meeting.

The last sentence of Article V consisting of these words "These officers shall be elected annually by ballot" shall be replaced by the following: At least three months prior to the annual meeting the secretary shall call for nominations for the various officers of the Society. Such call shall be accompanied by a list of previous officers. The three names receiving the highest number of votes for each office shall be placed on the official ballot to be sent to the voting members at least four weeks prior to the meeting. Voting shall be by mail, and the nominees receiving a plurality of votes shall be declared elected.

REPORT OF RESOLUTIONS COMMITTEE

Resolved, That the management of the Chalfonte-Haddon-Hall Hotel be given our expression of appreciation for the services rendered and courtesies extended to this Association during the twenty-ninth meeting of the Society.

Resolved, That this Society takes this opportunity of expressing its sincere appreciation to Dr. H. B. Tukey for the able and satisfactory manner in which he has handled the affairs of the Society during the past year.

Resolved, That the Society very much appreciates the many hours of work and excellent program provided for the members by the Editorial and Program Committees.

Resolved, That Prof. J. H. Clark of New Brunswick, New Jersey, deserves special commendation for his fine efforts in making such excellent pre-convention arrangements for the Society.

C. L. BURKHOLDER,
R. WELLINGTON,
V. R. GARDNER,
Committee.

REPORT OF NOMINATING COMMITTEE AND ELECTION OF OFFICERS

In its report the nominating committee submitted the names of officers and committees as shown on page ix of these Proceedings. The secretary was instructed to cast the vote of the Society for the officers and committees as nominated and their election was declared by the chair.

REPORT OF THE COMMITTEE ON LIBRARY FACILITIES

On account of existing economic conditions, your committee has deemed it inexpedient to push this matter at this time.

A. T. ERWIN, *Chairman.*

COMMITTEE TO COOPERATE WITH NATIONAL FERTILIZER ASSOCIATION

It was moved and carried that a committee of five be appointed by the outgoing president to act with other committees and the National Fertilizer Association in formulating recommendations for testing fertilizers on horticultural crops. The committee as appointed is: H. H. ZIMMERLEY, *Chairman*, C. B. SAYRE, OMUND LILLELAND, J. H. BEAUMONT, and R. W. HODGSON.

TREASURER'S REPORT FOR 1932

Receipts

Dues collected during 1932	$1,675.00		
Reports sold during 1932	939.96		
		$2,614.96	
Interest on money in savings accts.		31.91	
Balance on hand Dec. 15, 1931		1,859.39	
			$4,506.28

Expenditures

Dec. 22	W. F. Humphrey, programs and banquet tickets	$ 41.50	
Dec. 28	Society expenses, New Orleans meeting	137.25	
Dec. 28	Mimeographing, etc.	10.00	
Jan. 6	Postmaster, stamps	10.00	
Mar. 11	Postmaster, postcards	5.00	
Mar. 22	Postmaster, stamps	10.00	
Apr. 1	Postmaster, stamped envelopes	23.04	
Apr. 1	Secretary's fees for 1932	250.00	
Apr. 21	Addressograph Co., indexing cards	1.93	
May 10	Postmaster, stamps	10.00	
May 10	Franklin Square Agency, Proceedings ret'd	5.40	
Jun. 20	Postmaster, stamps	5.00	
Sept. 1	W. F. Humphrey, printing 1931 Proceedings	2,611.09	
Sept. 7	Postmaster, stamps	15.00	
Oct. 10	Postmaster, postcards	4.00	
Nov. 17	Postmaster, 1½c envelopes for mailing programs	8.00	
Nov. 17	W. F. Humphrey, balance charge mailing Proceedings	6.08	
	Exchange and tax on checks	.97	
	Total expenditures	$3,154.26	
	Balance on hand, December 20, 1932	1,352.02	
			$4,506.28

Respectfully submitted,

H. B. TUKEY, *Treasurer.*

Audited and found correct,

M. A. BLAKE,
V. R. BOSWELL,
ORA SMITH,
Committee.

The Growth Rate and Chemical Composition of the Hiley Peach from Stone Formation to Flesh Maturity

By Richard V. Lott, *Mississippi State College, State College, Miss.*

During the season of 1932, a study was made at the Mississippi Agricultural Experiment Station of the relationship between growth rate and chemical composition of the Hiley peach. Only that part of the fruit development period from the time when the stone was first hard enough to separate from the flesh to flesh maturity is included. The first sample was taken approximately 45 days after full bloom.

Five 10-year old Hiley peach trees of comparable vigor and fruit set were used. At each sampling date 10 fruits were picked at random from entirely around each tree, taken immediately to the laboratory and the 25 fruits of greatest uniformity of size, shape, and stage of maturity selected for growth measurements and chemical analysis. The fruits were weighed, the polar, suture, and cheek diameters determined in centimeters with a Vernier caliper, the volume determined by water displacement, the flesh cut from the stone, the stone with the kernel still inside weighed, and the weight of the flesh determined by the difference in weight between the whole fruit and the weight of the stone and included kernel. The stone was cracked, the kernel removed and weighed, and the weight of the stone determined by difference. The flesh, stone, and kernel were dried in an electric oven at 65 degrees C and then were ground into composite samples for chemical analysis. Thus all data were secured from the same fruits. The analytical methods of Murneek (4) were used.

Although growth is the increase of the organic constituents of an organ or a tissue, it is often inconvenient in horticultural investigations to measure this increase by the increase in dry weight. Therefore, some correlated and more easily determined measure of growth is preferred, if such a measure exists. Table I shows the methods which were used for the study of peach fruit growth. The data of Tables I and II show that all methods showed the same growth trend, but that only the dry weight measure showed the decreased growth rate which occurred from June 9 to 17 and the unchanging growth rate of June 24 to July 1. Diameter measurement is the easiest of the methods used, but it was the least accurate as shown by an increasing growth rate from May 19 to 26, while the dry weight rate was decreasing and a decreasing growth rate from June 17 to 24 when the dry weight rate was making its most rapid increase. Volumes calculated from the average and cheek diameters of Table I averaged approximately 14 per cent more and less, respectively, than the actual volume. It is obvious that external methods of measuring peach fruit growth are not accurate indices of the growth of the fruit.

TABLE I—GROWTH OF WHOLE FRUIT AND OF FLESH, STONE, AND KERNEL OF THE HILEY PEACH FROM STONE FORMATION TO MATURITY

Sample Date	Whole Peach							Flesh	Stone	Kernel
	Polar Diameter (Cm)	Suture Diameter (Cm)	Cheek Diameter (Cm)	Average Diameter (Cm)	Grams Fresh	Grams Dry	Volume (Cc)	Grams Dry	Grams Dry	Grams Dry
5–12	4.46	3.44	3.06	3.65	21.48	3.37	21.96	2.26	1.07	.044
5–19	4.78	3.68	3.30	3.92	26.34	5.14	26.24	2.89	2.20	.050
5–26	4.99	3.96	3.67	4.21	32.71	6.70	33.12	3.16	3.49	.052
6–2	5.03	4.01	3.72	4.25	34.44	7.39	34.56	3.37	3.95	.068
6–9	5.15	4.16	3.81	4.37	38.04	8.80	38.20	4.36	4.34	.100
6–17	5.41	4.42	4.19	4.67	46.22	9.78	46.68	4.77	4.83	.180
6–24	5.62	4.74	4.42	4.93	53.66	12.10	54.20	6.85	5.01	.232
7–1	5.96	5.08	5.04	5.36	70.78	14.42	74.60	9.29	4.86	.278
7–8	6.63	5.61	5.55	5.93	93.35	17.71	99.00	12.43	4.99	.304
7–12	6.72	5.63	5.65	6.00	95.68	17.81	102.60	12.80	4.65	.325

TABLE II—DAILY GROWTH OF THE HILEY PEACH FROM STONE FORMATION TO MATURITY

Sample Date	Whole Peach				Individual Tissues		
	Measure of Growth				Flesh	Stone	Kernel
	Average Diameter (Cm)	Volume (Cc)	Grams Fresh	Grams Dry	Grams Dry	Grams Dry	Grams Dry
5–12							
5–19	.039	.611	.694	.253	.090	.161	.0009
5–26	.041	.983	.910	.223	.039	.184	.0003
6–2	.006	.206	.247	.099	.030	.066	.0023
6–9	.017	.520	.514	.201	.127	.056	.0046
6–17	.038	1.060	1.023	.123	.051	.074	.0100
6–24	.037	1.074	1.063	.331	.297	.026	.0074
7–1	.061	2.914	2.446	.331	.349	—.021	.0066
7–8	.081	3.486	3.224	.470	.449	.019	.0037
7–12	.018	.900	.585	.025	.093	—.085	.0052

Tables I and II show that with one exception (June 24 to July 1), the dry weight of the flesh paralleled that of the whole peach. The stone reached its greatest dry weight by June 24, showing that it is the first of the three tissues of the fruit to reach physiological maturity. The comparatively rapid growth rate of the kernel at the time of the last sample indicates that it is the last part of the fruit to mature. Apparently, the tissues of the Hiley peach reach physiological maturity in the order stone, flesh, kernel.

It is shown in Table II that, during the week May 26 to June 2 when the flesh reached its slowest growth rate and the growth rate of the stone was rapidly decreasing, the kernel was increasing very rapidly in growth rate. During this time the cotyledons were forming and were ¼ inch long on June 2. The decreased growth rate of the flesh and whole fruit from June 9 to 17 occurred when the growth rate of stone was increasing and the kernel was making its most rapid growth. On June 17, the cotyledons were the full length of the kernel showing that they developed during a period when the kernel was reaching its maximum growth rate. It is significant that the "final swell" of the fruit, which was due to increase in size and dry weight of the flesh, occurred after the stone had reached nearly its maximum dry weight and the rate of growth of the kernel was decreasing. It can be seen in Table I that from May 26 to June 17 the stone and kernel constituted over 50 per cent of the dry weight of the fruit. These facts show that the stone and kernel were the dominant tissues of the fruit until the stone was nearing its maximum dry weight and the kernel had passed its maximum growth rate. Extremely erroneous impressions would be gained if stone and kernel growth were measured physically. The stone did not increase in size after May 26 but increased nearly 50 per cent in dry weight, while the kernel did not increase in size after May 12 but increased nearly 800 per cent in dry weight. The above data emphasize the importance of measuring growth in terms of dry weight.

The data of Table III show that, although the percentage of both water soluble and total nitrogen in the flesh decreased during the period studied, the total amounts increased, due to the increase in size of the fruit. This shows the constant need of nitrogen by the developing flesh. The highest percentages and greatest amounts of both water soluble and total nitrogen in the stone were present May 26 when the greatest growth rate of the stone was occurring. The complete absence of water soluble nitrogen in the stone after June 24, when it reached its greatest dry weight, shows that it had reached physiological maturity at that time. The decrease in the amount of nitrogen in the stone after May 26 while the amount in the kernel was increasing indicates that it was being translocated from the stone to the kernel, and particularly after June 24, when the stone had reached physiological maturity. The fact that the percentage and amount of water soluble nitrogen in the kernel was

TABLE III—CHEMICAL COMPOSITION OF THE FLESH, STONE, AND KERNEL OF THE HILEY PEACH

Sample Date	Percentages of Fresh Weight							Grams per 100 Fruits						
	Water Soluble N	Total N	Total Sugars	Starch	Hemicellulose	Ash	Ether Extract	Water Soluble N	Total N	Total Sugars	Starch	Hemicellulose	Ash	Ether Extract
							Flesh							
5-12	.09	.20	3.66	.13	.60	.42	—	1.37	3.04	55.60	1.82	9.11	6.38	—
5-19	.09	.19	2.87	.39	.78	.48	—	1.76	3.72	56.14	7.63	15.26	9.39	—
5-26	.08	.18	2.19	.19	.98	.53	—	2.04	4.59	55.87	4.85	25.00	13.52	—
6-2	.14	.21	1.63	.13	1.01	.66	—	3.76	5.64	43.78	3.49	27.13	17.73	—
6-9	.09	.19	3.01	.13	.74	.62	—	2.72	5.75	91.05	3.93	22.39	18.76	—
6-17	.09	.21	2.47	.16	.88	.67	—	3.43	8.01	94.26	6.11	33.58	25.57	—
6-24	.07	.15	4.78	.15	1.01	.56	—	3.22	6.91	220.07	6.91	46.50	25.78	—
7-1	.07	.13	4.71	.13	.60	.47	—	4.44	8.25	298.99	8.25	38.09	29.84	—
7-8	.05	.10	7.10	.31	.28	.39	—	4.32	8.63	612.73	26.75	24.16	33.66	—
7-12	.06	.12	7.92	.22	.23	.34	—	5.34	10.69	705.36	19.59	20.48	30.28	—
							Stone							
5-12	.05	.23	.18	.39	4.13	.52	—	.28	1.30	1.02	2.20	23.29	2.93	—
5-19	.08	.29	.73	.77	8.41	.60	—	.49	1.77	4.46	4.70	51.39	3.67	—
5-26	.09	.31	.34	1.32	11.46	.55	—	.65	2.23	2.45	9.50	82.51	3.96	—
6-2	.08	.29	trace	1.63	13.35	.46	—	.55	2.00	trace	11.26	92.25	3.18	—
6-9	.07	.25	.16	1.79	13.16	.39	—	.49	1.75	1.12	12.51	91.99	2.73	—
6-17	.03	.19	trace	1.91	13.08	.34	—	.22	1.39	trace	13.94	95.48	2.48	—
6-24	.01	.16	trace	2.14	14.13	.25	—	.07	1.12	trace	15.00	99.05	1.75	—
7-1	.00	.10	trace	2.20	14.27	.25	—	.00	.67	trace	14.63	94.90	1.66	—
7-8	.00	.10	trace	2.26	14.50	.26	—	.00	.64	trace	14.51	93.09	1.67	—
7-12	.00	.10	trace	2.15	14.02	.15	—	.00	.61	trace	13.03	84.96	.91	—
							Kernel							
5-12	.18	.36	—	—	—	—	.65	.11	.22	—	—	—	—	.40
5-19	.24	.44	—	—	—	—	.48	.16	.29	—	—	—	—	.32
5-26	.28	.48	—	—	—	—	.46	.19	.32	—	—	—	—	.31
6-2	.37	.61	—	—	—	—	1.26	.24	.40	—	—	—	—	.83
6-9	.43	.67	—	—	—	—	2.51	.34	.52	—	—	—	—	1.96
6-17	.82	1.27	—	—	—	1.13	7.45	.60	.93	—	—	—	.82	5.44
6-24	1.24	1.89	—	—	—	1.53	13.39	.74	1.13	—	—	—	.92	8.03
7-1	1.34	1.90	1.00	2.84	3.58	1.72	16.17	.88	1.25	.66	1.87	21.36	1.14	10.67
7-8	1.45	2.05	2.02	3.28	2.96	1.67	20.28	.91	1.29	1.27	2.07	.86	1.05	12.78
7-12	1.57	2.22	2.46	4.23	.76	1.97	23.23	.94	1.33	1.48	2.54	.46	1.18	13.94

Sugars and hemicellulose expressed as dextrose.

increasing on July 12 when the flesh was soft ripe, shows that it probably attains physiological maturity after both the stone and flesh, as shown in Tables I and II.

It is interesting to note that on June 2 when the flesh was making its slowest growth (Table II), it also had the lowest percentage and amount of total sugars. The decreased growth rate of the flesh on June 17 (Table II) coincides with a decrease in percentage of total sugars, but the amount of sugars had increased since the last sample. However, the rate of accumulation of total-sugars had decreased. The data show that on June 2 when the total sugars in the flesh were at a minimum the hemicellulose was high, on June 9 the total sugars had increased while the hemicellulose had decreased, and on June 17 the percentage of total sugars had decreased while the percentage of hemicellulose had increased. These facts and the rapid decrease of hemicellulose after June 24 when the sugars were accumulating most rapidly suggest the existence of a total sugar-hemicellulose equilibrium in plant tissues. The possibility of such an equilibrium is given additional weight by the data of Nightingale (5) which show, in the flesh of the Elberta peach, a decrease of hemicellulose and an increase of total sugars as the fruit ripened, and by the work of Murneek (4) who found that, in the new growth of the apple spur at flowering, the concentration of hemicellulose was lowest when the amount of total sugar was highest and vice versa.

Very little sugar was found in the stones. The values for the first three samples may be too high on account of the difficulty of separating all of the flesh from the stone in those samples. Unfortunately, the 25 fruits did not provide enough material for accurate carbohydrate analyses of the kernels except in the last three samples. Analyses were made of the other samples but because of doubtful accuracy they were not included. The increase in sugars in the kernels while the hemicellulose was decreasing points again to a possible total sugar-hemicellulose equilibrium. The increase in starch during this time suggests in addition the possibility of a hemicellulose-starch-sugar equilibrium. The decrease in the amounts of starch and hemicellulose in the stone after June 24 indicates that these substances may have been transformed to sugars and translocated to the kernel to be used in growth or as the source of the increasing amount of ether extract.

The data show that the greater part of the ash constituents of the fruit was in the flesh. The decrease in ash in the stone after June 9 indicates that some of these materials were being translocated to the still developing kernel.

Both the dry weight determinations and the chemical analyses show that the stone was the first of the three components of the fruit to reach physiological maturity, the flesh second, and the kernel last. The flesh did not make its most rapid growth until after the stone was near its maximum dry weight and its maximum

amounts of nitrogen, starch, hemicellulose, and ash. The kernel had made its most rapid growth before the flesh reached its greatest growth rate. These data combined with the fact that the stone and kernel comprised over 50 per cent of the dry weight of the fruit from May 26 to June 24 show that the stone and kernel were the dominating tissues of the fruit until their period of greatest activity was past. There was apparently present the dominance of reproductive tissues over vegetative ones that has been shown by Murneek, (3, 4), the stone and kernel representing reproductive tissues and the flesh a vegetative tissue. The kernel seemed to be dominant over the stone since the stone growth rate decreased while the growth rate of the kernel was rapidly increasing. While the kernel is the only strictly reproductive tissue of the fruit, the stone is more intimately associated with it than is the flesh, since the stone protects the kernel and apparently was the source of materials for kernel development after the stone had reached its maximum dry weight. It seems probable that materials are translocated from the flesh to the kernel after the flesh is mature. The anatomy of the peach is such that elaborated materials can be translocated from the flesh and stone to the kernel.

The data which have been presented have a bearing upon peach fruit thinning. Since increase in volume of fruit after stone formation was due to the increase in the amount of flesh, and over 60 per cent of the increase in dry weight was due to the increased dry weight of the flesh it is obvious that the growth rate of the fruit must be low during the period of stone hardening because the stone and kernel are dominant over the flesh during this period. Therefore, this period of slow growth rate of the fruit would occur regardless of the time of fruit thinning. The marked increase in fruit size which is sometimes secured from late thinning is due to the removal of competition of developing flesh during the "final swell" of the fruit. This competition is largely a carbohydrate one as shown by Table III. The data of Table III also show that the stone and kernel are made up predominantly of complex carbohydrate materials. Furthermore, the analyses fail to account for a large part of the materials in the stone. This is shown by the fact that on June 24, when the stone was at its maximum dry weight, its dry weight percentage was 71.47, while the total of the materials analyzed for was only 16.68 per cent. This extra material must have been cellulose or ligno-cellulose. If the removal of competition for simple carbohydrates, as in the flesh during the time of the "final swell," gives increased fruit size at maturity, it logically follows that the thinning of fruit immediately after the June drop should be more effective because of the removal of competition between fruits for the complex carbohydrates of high molecular weight which go to make up a large part of the stone and kernel, and because early thinning prevents the utilization of carbohydrates in the formation of the

stones and kernels which are removed in late thinning. Undoubtedly, early thinning is a means of saving large quantities of carbohydrates because of the predominance of carbohydrates of high molecular weight in the stone and kernel. This conservation of carbohydrates should be greater in large-stoned varieties like Elberta than in sorts such as Hiley which have medium-sized stones. Even though early thinning may not always result in greater fruit size than late thinning, as has been reported (1, 2), there can be no question of the fact that early thinning, under conditions similar to those of this investigation, would conserve carbohydrates that would be used for increased fruit growth, for the formation of fruit buds, for vegetative extension, or for storage purposes.

Acknowledgments

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Growth Study of the Peach Fruit *

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A STUDY of the growth of fruits is being made at Davis in connection with fruit thinning experiments. The methods used were similar to those previously described (1). Cyclic growth seems to be characteristic of many stone fruits. It is firmly fixed in many peach varieties and appears regularly year after year (2, 3, 4, 5). There are three distinct growth periods: a rapid increase early in the season, followed by a depressed growth rate, and finally the accelerated period in which the fruit makes its greatest increase. The changes in the rate of growth are generally quite abrupt as the fruit passes from one period to the other.

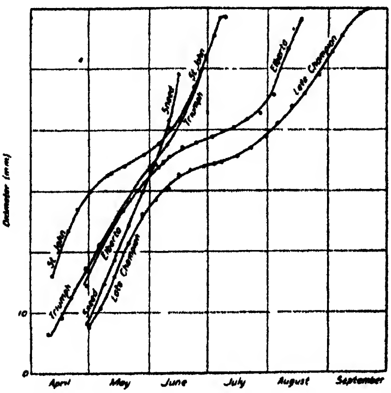

FIG. 1. Growth of the peach fruit as measured by increase in diameter. Note the absence of cyclic growth in the Sneed and Triumph varieties.

Measurements of the cross diameter have been made on the following varieties: Elberta, Lovell, St. John, Sneed, Triumph, Levi, and Late Champion. Some of the data, gathered over a number of seasons and therefore not strictly comparable, are graphically presented in Fig. 1. The most striking fact is the absence of the cyclic growth in the Triumph and Sneed varieties. The similarity in growth of early and late varieties is also of interest. Two conclusions seem justified from the data: (1) the development of the pit cannot be considered as a factor responsible for the cyclic growth, and (2) the time of maturity and the length of the growing season do not seem to be definitely responsible for its occurrence. The St. John, an early variety, exhibits distinct periodic growth.

It has been suggested (6) that the period of shoot elongation coincides with the depressed period of growth. Extensive measurements have not been made but seasonal growth data on 15 to 25 shoots on several varieties indicate that under California conditions the major shoot growth is generally over before the second growth phase sets in. In 1929 the Elberta peach had practically completed its flush of spring growth by June 1, whereas the fruit growth did not exhibit any signs of entering into the depressed phase until June 21, 3 weeks later.

Nor does the size of crop seem to be responsible for the period of depressed growth. A 10-year-old Elberta tree in 1929 had its crop reduced by frost during the blooming period so that it matured less

than 20 fruits. Yet the growth rate of these fruits in Period II is as low or lower than in seasons of normal tree loads. The extent of this period, however, was shortened in this season of an extremely light crop (Table I).

The extents of the periods of growth and their relations to the size of fruit and time of harvest may be studied from the data obtained on the Elberta variety over a period of years. (Table I).

The size of the fruit at the end of the first period may be a criterion of the ultimate size of the Elberta peach at the time of harvest. The 1923 and 1929 seasons produced large fruits at harvest and the peaches were considerably larger at the inception of the second period than they were in 1927 and 1930, when the harvested fruit was small. A popular opinion exists among growers that the size of fruit at the end of the first growth period forecasts its size at harvest. The apricot data (1) did not seem to confirm this idea and the peach data in Table I, though in accord with the growers' opinion, are not extensive enough to make any very definite statement.

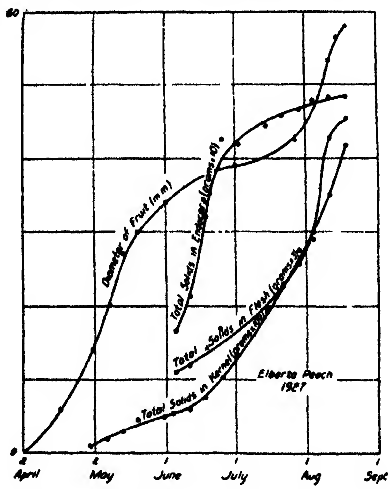

FIG. 2. Development of total solids in the flesh, endocarp and kernel in the peach fruit in relation to growth as measured by increase in diameter of the fruit.

There appears to be no correlation between the extent, the total growth, and the rate of growth in the second period and the size of fruit at harvest.

The extent of the third period is probably the most important factor in determining the size of the fruit and therefore precludes possibly any predictions based on pre-harvest growth performance. Though in the third period the 1927 season has the most rapid rate, its short duration makes it evident that even if the rate of increase were determined in the early part of the period, it would be of little value as a criterion of ultimate size. The importance of the third period is brought out more clearly later.

The analyses for the season 1927 (Fig. 2), which are confirmed by similar studies in 1923 and 1925, present the weekly changes in the green and dry weights of the components of the fruit. The discussion which follows is based on the averages of the data obtained in the three seasons.

The flesh which normally represents 94 per cent of the weight of the ripe fruit develops approximately two-thirds of this during an interim preceding harvest which may vary from 20 to 40 days, de-

TABLE I—SUMMARY OF GROWTH DATA OF THE PEACH FRUIT (ELBERTA) FOR FIVE SEASONS

Season	Period I				Period II				Period III				Diam. at Harvest (mm)	Total lgth. of Season (Days)
	Date	Extent (Days)	Growth (mm)	Rate per Day	Date	Extent (Days)	Growth (mm)	Rate per Day	Date	Extent (Days)	Growth (mm)	Rate per Day		
1923....	3/14–5/26	74	41	.55	5/27–6/26	31	7	.23	6/27–8/8	43	27	.63	75	148
1925.....	3/14–5/19	67	42	.63	5/20–7/1	43	1	.02	7/2–8/8	38	20	.53	63	148
1927....	4/3–6/1	60	34	.57	6/2 –7/27	56	8	.14	7/28–8/15	18	16	.89	58	134
1929....	4/4 –6/12	70	47	.67	6/13–7/5	23	1	.04	7/6 –8/23	49	32	.65	80	142
1930....	3/26–5/19	55	34	.62	5/20–6/20	32	8	.26	6/21–7/21	31	17	.55	59	118

pending on the season. This accelerated growth of the flesh is reflected in a rapid increase in the diameter of the fruit and its duration corresponds to that part of the growth curve designated as Period III.

The percentage of total solids in the flesh remains rather constant throughout the entire growing season. A slight increase in the moisture content of the flesh previous to harvest seems to be consistent in all the seasons studied. The percentage of total solids in the flesh of the ripe peach varies from 13 to 15, depending upon the season, with the average of all seasons as 14.0 per cent.

The rate of increase in weight of dry matter in the flesh corresponds to that in the green weight since the percentage of total solids in this portion remains fairly constant in the growing fruit. The total solids in the flesh at harvest represents from 72.6 to 76.2 per cent of the total solids in the whole peach. The average for the three seasons is 74.8 per cent. Two-thirds of this is developed in the last 20 to 40 days of growth so that at least 50 per cent of the total solids in the peach crop accrues during this last short period of growth. It would seem that this third period is one of great metabolic activity which should be reflected throughout the tree. Not only is there a large withdrawal of carbohydrates in this short interval, but also a large movement of mineral constituents into the fruit.

The endocarp which represents 5.4 per cent of the green weight of the fruit makes its major increase relatively early in the season. In 1923 and 1925 it attains its maximum green weight 114 and 117 days, respectively, after full bloom. In 1927, however, this interval is only 83 days. The variations in the weight of this component seem also quite large. In 1923 and 1925 the endocarp in the ripe fruit weighs 10.0 and 9.6 grams, respectively. In 1927 this is reduced to 6.5 grams.

Whereas the percentage of total solids in the flesh remains constant, a marked increase is evident in the endocarp. In 1923 and 1925 the endocarp at the earliest separation from the flesh contains 21.9 and 21.1 per cent dry matter. In 1927 it is 28.2 per cent. A very rapid increase occurs which in all three seasons noted above is concluded approximately a month preceding harvest. At maturity the percentages of total solids in 1923, 1925, and 1927, listed in the same sequence, are 77.9, 73.0, 74.8, an average of 75.2 per cent in this part of the fruit.

The actual weights of dry matter in the endocarp listed in the same chronological order are 7.8, 7.1, and 4.8 grams and represent 22.7, 25.7, and 22.3 per cent of the total solids in the entire fruit in their respective seasons. The maximum increase in total solids in the endocarp consistently takes place during the middle of Period II (the depressed period of growth).

The development of the kernel can be followed most readily. In 1923 its green weight was of the same magnitude 10 weeks after bloom as it was at harvest. In 1925 and 1927 a similar relationship

is observed 11 and 10 weeks after full bloom, respectively, indicating an early development on a green weight basis. Its weight at harvest varies from .76 grams in 1923 to .93 grams in 1925. The average green weight is .82 grams and represents approximately 0.5 per cent of the weight of the whole fruit.

The kernel like the endocarp shows an increase in the percentage of dry matter which, in the case of the kernel, however, continues until maturity. It differs from the endocarp in its development in that its major increase in per cent of total solids comes later in the growing season. The percentage of dry matter remains relatively low (approximately 7 per cent) and constant until 13 weeks after bloom from whence its rate of increase becomes more marked as the fruit approaches maturity. At maturity the dry matter in the kernel varies from 49.2 per cent in 1925 to 53.6 per cent in 1927. The average for the three seasons is 50.7 per cent.

From the above discussion it is evident that the increases in green weight and dry weight of the kernel are not concurrent developments. In general the kernel manifests its greatest increase in actual weight of dry matter during the third period of growth. The fully developed kernel contains from .37 grams (1923) to .46 grams (1925) of total solids. The average for the three seasons is .41 grams, which represents 1.5 per cent of the total solids in the entire peach.

The flesh at all times contains the greatest proportion of not only the organic but also the inorganic materials. Its rapid development in the third period suggests that delaying thinning beyond the inception of this period might cause appreciable reduction in the reserves in the tree and in the size of fruit.

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Seed Size in Relation to Fruit Size in the Peach: The Fourth Report on the Illinois Thinning Investigations

By M. J. DORSEY, and R. L. MCMUNN, *University of Illinois, Urbana, Ill.*

EMPHASIS has been placed upon three fairly distinct growth periods in the fruit of the peach in some of the more recent research (1, 2, and 4). The significant difference between these growth periods lies in the rapid development of the seed* parts in the first period, the relatively slow expansion of the flesh in the second, to be followed in the third period by a very pronounced increase in the flesh as maturity is approached. On account of the fact that the stone develops so early in the growth of the fruit, its relationship to the flesh becomes of considerable interest in connection with the thinning problem. Accordingly this study, the fourth in the series on thinning, (3, 4, 5, 6, 7, and 8) deals with four phases of this relationship: (1) the seed-flesh relationship during growth, (2) the seed-flesh relationship in fruits of different sizes, (3) the influence of cultural variables upon stone, and (4) the influence of thinning upon the size of the stone. These headings will be taken up in detail in this order.

THE "SEED"-FLESH RELATIONSHIP DURING GROWTH

Since the growth of the "seed" takes place for the most part during the first period its relationship to the flesh would not be expected

TABLE I—THE PERCENTAGE INCREASE IN THE FLESH OF ELBERTA DURING THE SECOND AND THIRD GROWTH PERIODS. THE DATA ARE BASED UPON A RANDOM SELECTION OF 50 FRUITS TAKEN FROM THE GROUND AT EACH THINNING DATE WITH THE EXCEPTION OF THAT OF AUGUST 8, WHICH WAS PICKED HARD RIPE FROM THE PLOT THINNED APRIL 30 (1927)

	Date of the Fruit Collections During the Second and Third Growth Periods						
	June 23	June 28	July 7	July 13	July 20	July 26	Aug. 8
Ave. suture diameter (inches).....	1.51	1.53	1.57	1.62	1.82	1.95	2.26
Ave. wt. of fruit (grams).........	30.0	34.1	35.9	39.9	47.1	59.2	125.2
Ave. wt. of seed (grams).........	6.6	7.5	6.5	6.9	8.2	7.5	11.1
Per cent flesh by weight..........	78.2	78.2	81.7	82.5	82.6	87.4	91.1

*There is need in peach literature for a general term to be used in referring to the stone and its contents. "Seed" is used in that sense in this paper. Stone, pit and endocarp refer to the outer hardened part of the "seed." The kernel (botanically the seed) is that part enclosed by the stone and, at maturity, is composed of the seed coats, cotyledons, embryo, etc. In popular usage among horticulturists seed, stone, and pit are all used interchangeably in the same sense as "seed" is used here.

to change after the stone had hardened and its size limits had thus become established. The data brought together in Table I, starting June 23 at which time the endocarp could first be separated from the flesh, deal specifically with "seed"-flesh relationship during the second and third growth periods.

While there is some irregularity in the weight of the "seed" at the different dates, it will be seen that it increases in weight toward maturity. The suture diameter and the weight of fruit show the characteristic rate of increase during the two periods. It will be noted also that the percentage increases from 78 per cent when the stone has hardened to 91 per cent, at maturity. In some of the larger fruits, in Table II, the flesh constitutes 95 per cent of the weight of the peach.

TABLE II—THE RELATIONSHIP BETWEEN THE "SEED" AND THE FLESH, AT MATURITY, IN FRUITS OF FRUIT IN EACH SIZE CLASS FOR EACH TREE. THE TREES FROM WHICH THIS FRUIT WAS EARLY SUMMER CULTIVATION, FOLLOWED

Source of Material			Size of Fruit					
			1½" down			1½–1¾"		
Variety	Crop Year and Location	Treatment	Ave. Wt. of Fruit	Ave. Wt. of "Seeds"	Per cent Flesh	Ave. Wt. of Fruit	Ave. Wt. of "Seeds"	Per cent Flesh
Elberta.. .	Bates, Centralia, 1929	Thinned						
		June 5 to 5"						
		June 27 to 5"						
		July 16 to 5"						
		Check				2.11	.275	86.9
		Orchard run thinned						
Elberta....	U. of I. Olney Farm, 1931	Thinned						
		May 26 to 5"						
		May 26 to 10"						
		June 23 to 5"						
		June 23 to 10"						
		July 18 to 5"						
		July 18 to 10"						
		Check						
Elberta....	McBride, Villa Ridge, '31	Tree 1 pruned heavily in '31 unthinned						
Champion	U. of I. Farm, Urbana, '31	Tree 1 thinned to 5"	1.26	.122	90.3	1.45	.134	90.8
		Tree 2 thinned to 5"	1.36	.120	91.2	1.50	.136	90.9
		Tree 3 thinned to 5"	1.29	.129	90.0	1.42	.133	90.6
Delicious..	U. of I. Farm, Urbana, '31	Thinned*						
		July 21 to 5"						
		Check				1.43	.134	90.6
So. Haven	U. of I. Farm, Urbana, '31	Thinned*						
		July 21 to 5"				1.71	.108	93.7
		Check				1.63	.123	92.6
Waterloo..	U. of I. Farm, Urbana, '31		1.32	.123	90.7	1.45	.123	91.5

*Larger fruit removed in thinning.

The "Seed"-Flesh Relationship in Fruits of Different Sizes

In view of the fact that the flesh constitutes an increasingly larger part of the fruit toward maturity, the question arises as to the "seed"-flesh relationship in peaches of different sizes. Data bearing upon this point have been summarized in Table II for five varieties.

Without going into detail it will be seen (Table II) that in all varieties the "seed" constitutes a smaller proportion of the fruit in the larger sizes. In Elberta some of the largest peaches are as high as 95 per cent flesh when hard ripe, while in some of the smaller fruits of this variety the percentage of the flesh is as low as 87 per cent.

of Different Sizes. The Data Given in Ounces are Based Upon Approximately 50 Pounds
Obtained Were Given 3 to 5 Pounds of Nitrate of Soda Before Bloom and the Usual
by a Cover Crop in the Fall

Size of Fruit											
1¾-2"			2-2¼"			2¼-2½"			2½" up		
Ave. Wt. of Fruit	Ave. Wt. of "Seeds"	Per cent Wt. of Flesh	Ave. Wt. of Fruit	Ave. Wt. of "Seeds"	Per cent Flesh	Ave. Wt. of Fruit	Ave. Wt. of "Seeds"	Per cent Flesh	Ave. Wt. of Fruit	Ave. Wt. of "Seeds"	Per cent Flesh
			3.89	.300	92.3						
			3.66	.296	91.9						
			3.34	.281	91.2						
3.00	.284	90.5	3.33	.289	91.3						
						6.02	.387	93.6	7.34	.420	94.0
			3.60	.243	93.2	3.98	.246	93.8			
			3.65	.261	92.8	4.62	.282	93.9			
			3.67	.237	93.5				4.80	.261	94.6
			3.22	.243	92.4	3.50	.233	93.3	4.78	.257	94.6
			3.69	.251	93.2	4.16	.251	94.0	4.72	.306	93.5
			4.15	.225	94.6	4.22	.217	94.9	5.36	.268	95.0
2.61	.226	91.4	3.92	.270	93.1	4.18	.262	93.8			
			4.14	.334	91.9	4.82	.343	92.9	6.22	.388	93.8
1.87	.136	92.7	2.34	.145	93.8						
1.87	.151	91.9	2.50	.137	94.5						
1.94	.137	92.9	2.36	.145	93.9						
1.69	.147	91.3	2.36	.139	94.1	3.00	.154	94.9			
1.79	.148	91.7	2.24	.141	93.7	3.34	.158	95.3			
2.20	.135	93.9	2.38	.147	93.8	3.99	.176	95.6			
2.05	.144	93.0	2.67	.169	93.7	3.34	.200	94.0			
1.95	.144	92.6	2.51	.150	94.0						

TABLE III—THE RELATIONSHIP BETWEEN THE SIZE OF THE STONE AND THE SIZE OF THE FRUIT

Line	Source of the Material Measured				Length of Stone (Cms)						
	Orchard	Treatment	Thinning	Fruit Size	3.0	3.1	3.2	3.3	3.4	3.5	3.6
1	Bates, Centralia	5 lbs.	None '29	1¾"–down	1				5	7	27
2		$Ca(NO_3)_2$	None '29	1¾–2"					1	3	8
3	McBride, Villa Ridge	2 lbs. $NaNO_3$	6/3/29	2–2¼"						2	3
4			6/5/29	2–2¼"						3	7
5			5/3/29	2–2¼"							
6			None	2–2¼"							
7	Endicott, Villa	3 lbs.	6/3/29	2–2¼"						1	3
8	Ridge	$NaNO_3$	6/3/29	2–2¼"					1	1	8
9			6/3/29	2–2¼"		1					2
10			6/3/29	2–2¼"					1		6
11			6/3/29	2–2¼"							2
12			None	2–2¼"					1	6	4
13			None	2–2¼"							5
14			None	2–2¼"							1
15			None	2–2¼"				1	2	5	19
16	Bates, Centralia	5 lbs.	6/5/29	2–2¼"						2	3
17		$Ca(NO_3)_2$	6/27/29	2–2¼"							6
18			7/16/29	2–2¼"						5	7
19			None	2–2¼"							5
20		None	6/3/31	2–2¼"					6	9	15
21		3 lbs. Cyanamid	6/1/29	2–2¼"				2	1	8	10
22		5 lbs. $NaNO_3$*	6/1/29	2–2¼"						3	8
23		3 lbs. $(NH_4)_2SO_4$	6/1/29	2–2¼"					1	10	10
24		5 lbs. $NaNO_3$*	6/1/29	2–2¼"					1	3	12
25		5 lbs. $NaNO_3$	6/6/29	2–2¼"					1	5	17
26		5 lbs. $NaNO_3$*	6/1/29	2–2¼"						2	15
27		5 lbs. $Ca(NO_3)_2$	6/1/29	2¼–2½"							
28	Endicott, Villa	3 lbs.	6/3/29	2¼–2½"					1		
29	Ridge	$NaNO_3$	6/3/29	2¼–2½"							
30			6/3/29	2¼–2½"							
31			6/3/29	2¼–2½"							
32	Bates, Centralia	Not fertilized '28 & '29		2¼"–up						1	5
33	Endicott, Villa Ridge	3 lbs. $NaNO_3$	6/3/29	2½"–up							
34	Bates, Centralia	5 lbs. $Ca(NO_3)_2$	6/1/29	2½"–up							
35	W. A. Hartline, Anna, Ill.	Fertilized	Thinned	2¾"–up							3
36	W. P. Tufts, Davis, Calif.	Irrigated	Thinned							2	4
37	J. W. Beal, Dresden, O.	30-yr.-old trees in sod	Not thinned		1	1	5	12	24	21	30

*Five pounds of nitrate of soda applied July 10 each year.

N ELBERTA. THE CULTURAL VARIABLES UNDER CONSIDERATION ARE GIVEN FOR EACH LOT

Length of Stone (Cms)															Average Length of Stones (Cms)	Line
3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	5.0	5.1		
39	36	28	5	2											3.74	1
18	30	33	42	8	6	1									3.88	2
7	18	37	52	25	6										3.99	3
10	29	37	30	31	2	1									3.89	4
1	6	18	39	46	26	9	4	1							3.94	5
5	21	23	48	35	10	7	1								4.00	6
10	25	43	33	23	9	2		1							3.94	7
13	31	37	29	24	4	2	1								3.90	8
4	24	16	30	22	10	5	1								3.97	9
16	29	38	35	18	5	1	1								3.89	10
11	19	30	41	29	13	4									3.97	11
26	34	30	28	16	4	1	4								3.86	12
6	22	27	37	28	12	9	3								3.99	13
11	12	20	47	28	24	4									4.01	14
27	42	31	15	7	1										3.80	15
9	15	25	46	26	19	4	1								3.94	16
5	13	23	48	21	26	3	5								4.01	17
24	33	40	26	11	4										3.85	18
21	31	30	34	16	10	2	1								3.94	19
37	29	31	19	4											3.78	20
25	47	27	26	4											3.81	21
20	44	39	28	3	3	2									3.85	22
31	45	28	18	6	1										3.80	23
12	45	30	32	8	7										3.86	24
27	36	32	19	7	5			1							3.83	25
24	34	38	26	8	2	1									3.82	26
	1	0	4	11	27	32	19	17	9	3	2				4.33	27
6	13	30	45	31	19	3	2								4.00	28
4	6	20	30	32	31	7	8								4.12*	29
6	8	13	35	35	32	17	3	1							4.08	30
2	3	10	26	44	39	14	7	4	1						4.13	31
13	30	44	33	20	4										3.90	32
			1		10	10	3	3							4.29†	33
				1	8	10	11	32	21	15	5	5		1	4.53	34
9	14	27	31	18	21	17	3	3	3		1				4.05	35
17	29	46	67	53	31	28	11	9	2						4.04‡	36
28	12	7	4	2	3										3.59	37

*138 stones measured. †27 stones measured. ‡300 stones measured.

The "seed"-flesh ratio is quite similar in the different varieties. Even with fruit below 1½ inches in Champion the flesh constitutes about 90 per cent of the peach. It will be seen also in Table III that the length of the "seed" tends to be greater in the larger fruits.

Recalling for the moment the rapid enlargement of the stone or endocarp in the first period, the stones from the heavily pruned, unthinned tree in the McBride orchard (Table II) are of special interest. This tree was "dehorned" February 18, 1931, in order to test the effect of heavy pruning the current season upon "seed" size. The data are based upon the "seeds" taken from 127 fruits. The stones in a given fruit size from this tree were larger than those from trees thinned early, or from those given an early spring application of as much as 15 pounds of nitrate of soda. These fruits were produced on shoots low in vigor—the so-called "hang wood"—since the more vigorous branches in the top of the tree were removed in pruning. The new growth induced by the pruning was vigorous and so dense that the fruit developed very little color.

Two important facts may be emphasized at this point in the discussion: (a) The flesh increases in amount, relative to the "seed," as maturity is approached and (b) while the larger peaches tend to have larger "seeds" the proportion of the peach which is flesh increases with size.

The "seed"-flesh relationship as analyzed above in Elberta may be somewhat different in other varieties. The season of ripening, the moisture supply, vigor of growth, the set of fruit, and cultural factors all have a bearing upon the amount of the flesh developed about the stone, which, except when "split," is quite fixed in each dimension after the hardening process sets in.

The Influence of Cultural Variables Upon Stone Size

It is generally known that the size of the fruit of a given variety varies greatly when grown under different conditions but how about the "seed" or more particularly the stone? The data obtained upon this point are arranged in Table III in the order of the size of the fruit from which the stones were obtained. Except where noted, 150 stones were measured in each of the different lots or classes. It will be recalled in the other studies in this series that a special sizer was constructed for use in the thinning experiments which separated the fruit from each treatment into classes differing by ¼-inch intervals. It is to be expected, therefore, that the range of variation in the stone size in the different groups will be somewhat greater than if obtained from fruit of a definite suture diameter.

A study of the data will show that stone size in Elberta varies greatly from trees grown under different conditions, and also from fruits of a given size. By comparing the "seed" size from different lots of fruit picked from the same tree it will be seen that the data here fall in line with that of Table II in showing that the larger peaches tend to have the larger stones. This tendency can best be

seen by comparing lines 1 and 2, 7 and 30, 8 and 31, 10 and 28, 11 and 29, and finally lines 20 and 22.

The smallest stones found in Elberta came from old trees, growing in sod and consequently in a low state of vigor, i.e., high carbohydrate trees (line 37). These were even smaller than the stones from fruit 1¾"-down borne by an unthinned tree, which had been given a spring application of 5 pounds of calcium nitrate (line 1). Irrigated peaches (line 36) have large stones, but in this instance not as large as peaches 2½"-up (lines 33 and 34). These last two lots of stones came from large peaches, borne by vigorous trees growing under favorable conditions and may be best described as high nitrogen trees in contrast to the trees of line 37. These instances indicate that the growing conditions of the first period have a marked influence upon stone size and are in accord with the common knowledge among growers that the peach may be noticeably larger at the stone hardening stage under some conditions than others.

In view of the trend of these results, it will be of interest to note the size of the stones from the fertilizer plots where some growth contrasts have been built up by differential treatments. Considering first the size of the stones, within the 2–2¼" class from the check trees in the Bates orchard (line 20) which have not been fertilized for 4 years, it will be seen that the distribution of the stone size and the average as well, falls below the stone size for the fertilized trees in the other blocks (lines 22, 23, 24, 25, and 26). The pit size is smaller from the trees to which Cyanamid had been applied (line 21). The stones of the 2¼"-up class from the unfertilized trees (line 32) are approximately of the same size as those from the 2–2¼" peaches borne by the fertilized trees. In the still larger fruits, orchard run, (line 34) from the Bates orchard the stone size falls in line with the general trend in the other lots. The trees in the Bates orchard were all thinned each year to approximately 5 inches, so that it may be said that these studies of stone size were made under conditions where there was not serious overloading.

The stones from the Endicott orchard (lines 28, 29, 30, and 31) were taken from trees of good vigor selected for their uniformity in appearance. Under these conditions the stones from a given fruit size were quite similar in length.

It appears, therefore, from a number of angles, that the size of the "seeds," or stones, and the size of the fruit are more or less closely related. The relationship might have been found somewhat closer had the "seeds" been taken from fruit of a given measured dimension instead or from a size class as separated out by the sizer used in the thinning experiments.

The Influence of Thinning Upon the Size of the Stone

It now remains to discuss the effect of thinning upon the size of the stone. Obviously thinning after the stone has reached its full dimensions would not have much bearing upon its size. It might be

expected, however, if stone size were increased by thinning that the earlier in the first period the thinning were done the greater would be the increase in size. It should be recalled at this point that the studies of the range in the time of effective thinning (4) showed that the earlier thinnings, starting when the young fruits averaged only 1.36 grams in weight and a month before the stone began to harden at the tip, did not have a measurable influence upon the size of the fruit when compared with the fruit thinned later. In view of these results the stone size of early thinned fruit will be especially interesting.

In studying this point, four trees in the McBride orchard were carefully selected for their uniformity in size and general growth conditions. Their vigor was about midway between the high carbohydrate condition as one extreme (line 37) and the high nitrogen trees as the other (line 34). One of the trees (line 5, Table III) was thinned May 3, when the young peaches were about ½-inch through the suture diameter. In thinning to a distance of approximately 5 inches, it was necessary to remove 4,300 fruits. The two adjacent trees (lines 3 and 4) were thinned a month later when the stones were practically full size and in the most advanced peaches were hardening at the tip. One tree was left unthinned as a check (line 6).

In this test it does not seem that the early thinning had much effect upon stone size within a given growth condition. In fact the larger stones came from the unthinned tree. Comparison was made of the stone size within a given fruit class in this experiment, as in the other measurements. This was thought to be a fair basis of comparison because if early thinning were to have a pronounced influence upon endocarp formation it would be expected to increase its extent of development in fruits of all sizes. This, however, was not the case.

There is additional evidence that early thinning does not affect stone size, within a given tree condition, in Table III. In some of the trees from the Bates orchard (lines 16, 17, 18, and 19) the thinning dates were June 5 and 27, and July 16. The pits began to harden at the tip a week or so after the first thinning. While the stones from the tree first thinned were slightly larger than from either of those thinned later the difference is well within the limits of tree variability. Here again the stones from the check trees (line 19) are quite similar in size to those from the thinned trees.

Further data regarding the effect of the time of thinning upon stone size may be seen in Table II. The trees at the University Farm, at Olney, were thinned May 26, June 23, and July 18. The last two thinnings were after the stones had hardened but in the first instance the thinning was about 2 weeks before that stage. Here again the earlier thinning did not result in an increase in the size of the stone within a given fruit size in tests with 5-year-old trees. In fact in the July 18th thinning to 10 inches (line 11) when it was possible to leave the larger fruits on the tree, the stones are smaller but the fruits larger than at earlier thinning dates. In this instance two fac-

tors should be kept in mind: First, the natural drop had eliminated the weaker fruits, and second, in thinning to 10 inches so late in the season, considerable of the load of the tree was removed so that the "release" was effective in inducing greater flesh growth.

Summary and Conclusions

In interpreting the results of this study, three things should be taken into consideration: First, the peach flower and hence the peach, is borne singly and not in a cluster as in the apple or cherry. There is therefore no direct competition between closely associated pistils or fruits. Secondly, the stone or endocarp is primarily, at least in size, a development of the early part of the season. i.e., of the first period of growth. Thirdly, the flesh on the other hand increases in amount most rapidly toward maturity or near the end of the third period. With these statements as a background, the following conclusions seem justified from this study.

1. The stone does not increase in size (split pits excepted) after the hardening process is under way. While the "seed" increases in weight slightly as it matures, it comprises a smaller and smaller part of the peach during the second and third growth periods.

2. The larger peaches tend to have the larger "seeds." The significance of this relationship commercially is that conditions should prevail during the first period which favor "seed" development or early growth in the peach as a whole if the larger sizes are to be reached. This does not, however, minimize the importance of favorable growing conditions toward maturity in increasing the size of the fruit.

3. The size of the stone, within a variety, varies greatly. Low carbohydrate trees produced the smaller "seeds" and high nitrogen trees the larger ones.

4. Early thinning did not, within a given tree condition, increase the size of the stones in fruit of a given size class as might be expected. The size of the stone, obviously, would not be affected by thinning after the completion of the hardening process.

5. The general growth conditions of the tree, i.e., whether high carbohydrate or high nitrogen, influenced stone size more than early thinning. The largest peaches are formed when growth conditions are favorable throughout the season, i.e., during all three of the growth periods. The largest peaches with the smallest "seeds" are produced when growth conditions are especially favorable only during the third period. Conversely peaches of a given size have the largest stones when the growth conditions during the early part of the season are favorable and the latter part, particularly during the final swell, are unfavorable.

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Further Studies on the Relation Between Leaf Area and Size of Fruit, Chemical Composition, and Fruit Bud Formation in Elberta Peaches

By J. H. Weinberger, and F. P. Cullinan, *U. S. Department of Agriculture, Washington, D. C.*

As a result of the previous season's work, evidence has been presented (2) to show that a definite relationship exists between number of leaves per fruit and the size and quality of Elberta and Late Crawford peaches. With increase in leaf area per fruit an increase in size and improvement in flavor was noted. The 1932 results reported herein fully corroborate these observations, and in addition include data on fruit bud formation on ringed branches.

Six branches on each of 10 Elberta peach trees growing in a 21-year-old orchard of the University of Maryland at College Park, were ringed, and different ratios of leaves per fruit were established. These branches were carefully selected for uniformity in vigor, size of leaf, and number and size of peaches borne. Six leaf-to-fruit ratios were used: 10, 20, 30, 40, 60, and 80, each of the 10 trees having a complete series. At the time of ringing, June 13, it was just possible to select those fruits which would probably survive the normal drop, though pit hardening did not occur until 3 weeks later. Terminal growth had not ceased and several pinchings of the terminals during the season were necessary to maintain the leaf ratios. The lower leaf ratios, 10 and 20, produced by far the greatest number of new leaves after ringing.

Circumference measurements of the fruit were made at weekly intervals, though only the data at time of picking are presented here. These measurements have been converted to a volume basis as being more nearly indicative of the actual size of the fruit. The average results are shown in Table I.

With 10 leaves per fruit, peaches attained a size of 66 cc (approximately 2 inches in diameter), while with 20 leaves per fruit, the final size was 102 cc (2¼ inches). With a greater number of leaves per fruit, the final size was increased though not directly proportionately. The branches having an 80-leaf ratio produced fruits averaging 150 cc, only 10 cc larger than the 60-leaf peaches. Thus the size of the peaches was increased 4 cc per leaf in the smaller leaf ratios by an increase in number of leaves, while with the larger leaf ratios the increment was only 0.5 cc per leaf. These results fully corroborate those obtained the previous year, though the fruit on all the leaf ratios was smaller, because of seasonal differences. These results are also in accord with those of Jones (1) working with Georgia Belle peaches under North Carolina conditions.

Although the peaches were growing at a comparatively rapid rate, marked response from ringing was immediately evident. Ten

TABLE I—THE RELATION OF NUMBER OF LEAVES TO SIZE AND COMPOSITION OF PEACH FRUITS (PERCENTAGE CALCULATED ON FRESH WEIGHT BASIS)

Number Leaves per Fruit	Final Size Fruit (cc)	Weight of Pits (gms)	Dry Weight (Per cent)	Reducing Sugars (Per cent)	Total Sugars (Per cent)	Acidity[1]	Osmotic Pressure Juice (Atm.)	Sugar-acid Ratio
10	66.3	6.09	13.2	2.92	7.18	49.8	15.7	.144
20	102.1	6.21	15.6	2.82	9.18	42.4	16.6	.218
30	118.1	6.33	16.1	3.01	10.17	41.4	18.5	.245
40	129.6	6.37	16.7	2.94	9.99	41.1	16.2	.244
60	144.0	6.56	19.0	3.40	11.77	46.5	19.2	.253
80	149.8	6.92	19.9	3.46	12.30	54.1	20.8	.228

[1]Acidity expressed as number of cc 0.1N NaOH required to neutralize 50 gms extracted fresh tissue.

TABLE II—THE RELATION OF LEAF AREA TO FRUIT BUD FORMATION AND COMPOSITION OF TERMINALS AND LEAVES (PERCENTAGE CALCULATED ON FRESH WEIGHT BASIS)

Number Leaves per Fruit	No. Fruit Buds per 100 Nodes	Terminals				Leaves			
		Dry Weight (Per cent)	Reducing Sugars (Per cent)	Total Sugars (Per cent)	Starch (Per cent)	Dry Weight (Per cent)	Reducing Sugars (Per cent)	Total Sugars (Per cent)	Starch (Per cent)
10	7	44.9	1.20	1.65	2.14	44.2	0.59	2.12	0.97
20	41	48.4	0.93	1.64	3.00	44.3	0.63	1.91	0.71
30	45	49.4	1.04	1.81	3.69	44.6	0.76	2.18	1.21
40	46	50.7	1.08	1.70	4.54	43.8	0.82	2.29	0.93
60	56	50.1	0.98	1.76	5.25	43.4	0.88	2.03	1.68
80	54	50.2	1.16	1.80	5.35	46.6	0.89	2.36	2.14

days after the adjustment of leaf ratios and ringing, the fruit with the 80-leaf ratio was over 36 per cent larger, with the 60-leaf ratio over 30 per cent larger, and with the 10-leaf ratio only 3 per cent larger than before ringing. Fruit on the other ratios showed intermediate values, correlated with leaf area. Later growth while not so rapid was in the same relative order. It is evident, however, that the response to thinning and ringing was immediate and profound.

Since thinning was done before pits were hardened one might expect the size of pits as well as fruits to have been affected. At picking time the pits were removed, and weighed, air-dry. The average results (Table I) showed that the heaviest pits were produced with the 80-leaf ratio, averaging 6.92 gms., and the lightest with the 10-leaf ratio, 6.09 gms. The other ratios were intermediate and directly correlated with leaf area.

It was noted previously that fruit on ringed branches tended to become larger than fruit on normal branches, and an attempt was made to determine the effect of ringing alone on size of fruit, using Georgia Belle peaches. Nine forked limbs, which bore from 20 to 80 peaches, were selected on June 23. One of the branches of each fork was ringed and the other was left not ringed. Exact leaf-to-fruit ratios were established on both branches and the rest of the tree thinned approximately to the same ratios. The average size of fruit at time of picking on branches not ringed was 64.4 cc; on the ringed branches, 77.0 cc or 20 per cent larger. On seven of the nine forks, having 30 leaves per fruit, the comparison was 66 to 76, a 16 per cent difference. On the other two forks adjusted to 50 leaves per fruit, the difference was 34 per cent, 60 on the not-ringed and 80 on the ringed branches. Thus the effect of thinning of fruit on ringed branches is not strictly comparable to thinning on normal branches. The accumulation of food caused by ringing the bark increases the efficiency of the individual leaf in sizing the fruit. The larger the leaf area per fruit, the more noticeable is this effect. Allowance should be made for this factor in interpreting results of this type on a practical basis.

As far as could be determined by tasting, flavor was improved with greater leaf area to 30 leaves per fruit, with little difference between 30-, 40-, 60-, and 80-leaf fruits. Chemical analyses (Table I) of the peaches showed an increase in total sugar content on a fresh weight basis, from 7.2 to 12.3 per cent from the 10 to the 80 ratios, respectively. A corresponding, almost proportional increase in dry weight of fruit also occurred with all leaf ratios, the 10-leaf-ratio peaches having only 2/3 as much dry matter as the 80-leaf-ratio fruit. Osmotic pressure of the juice determined by freezing-point depression, followed closely the total sugar percentages.

Total acidity of the fruit, however, was not a direct function of leaf area. The greatest acidity was decidedly in the lowest and highest leaf-ratios, as previously noted (2). Acidity values for fruit from the intermediate ratios, 30 and 40, averaged 41.4 and

41.1, respectively, compared with 49.8 for the 10-, and 54.1 for the 80-leaf ratios.

Interpreting these values as a sugar-acid ratio, often considered a dependable index of quality, the 10-leaf ratio runs .144, the 20-leaf ratio .225, and the 30-leaf ratio .246. Greater leaf areas than 30 showed but a slight increase in this value, the 80-leaf ratio being decidedly smaller because of extreme acidity.

Counts of the number of fruit buds produced on the ringed branches showed decided differences (Table II). Branches having 10 leaves per fruit produced only 7 fruit buds per 100 nodes, while 20 leaves per fruit had 41 fruit buds per 100 nodes. Greater leaf areas produced more fruit buds, with a maximum of 56 fruit buds per 100 nodes on branches having 60 leaves per fruit. Carbohydrate analyses of leaves and current-year terminals, made immediately after fruit harvest, closely correlate the figures on fruit bud formation. Starch in shoots increased regularly with greater leaf area from a minimum of 2.14 per cent in shoots having 10 leaves per fruit to a maximum of 5.35 per cent in shoots having 80 leaves per fruit.

With each increment in leaf area, a corresponding increase in starch was noted. A regular increase was also found in the reducing sugars in leaves, which, though not large, is significant in its regularity. As shown in Table II, leaves on branches having 10 leaves per fruit had 0.59 per cent reducing sugars, while leaves on branches having 80 leaves per fruit had 0.89 per cent reducing sugars. Similar values for the other ratios were intermediate. Leaf samples were taken between 2 and 4 p. m., shortly after fruit had been picked.

Total sugar and starch content in leaves, and sugar content in twigs were more variable, but all showed a trend toward increasing values with greater numbers of leaves per fruit. From this the conclusion may be drawn that fruit bud formation in peaches, under the conditions of these experiments, where nitrogen was not a limiting factor, is definitely associated with carbohydrate content, especially with conditions favoring starch accumulation in the shoots. Thinning, or increasing the number of leaves per fruit on ringed branches, caused the differentiation of a larger number of fruit buds. Branches having 20 leaves per fruit had almost six times as many fruit buds per 100 nodes as branches having 10 leaves per fruit. With ratios higher than 20, the increase was only about 10 per cent for each 10-leaf increment, with the exception of the 80-leaf ratio where a slight decrease in number of fruit buds formed, possibly attributable to experimental error, was noted. Considering that these results were obtained with ringed branches, it is evident that branches must be very heavily loaded with fruit to completely inhibit fruit bud formation, and that even a very light thinning on heavily loaded branches aids differentiation processes a great deal.

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The Gumming of Phillips Cling Peaches

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ABSTRACT

The complete paper will appear in a publication of the University of California Agricultural Experiment Station.

THE Phillips Cling, one of the leading varieties of canning peaches in California, suffers heavy losses in some years because of the presence of a mass of gum on the fruit, which in nearly all cases is accompanied by a pocket or cavity in the flesh. The gumming of this variety falls into at least three distinct types. One type seems to be due to mechanical injury, such as a limb rub or insect puncture. This type may appear any place on the periphery of the fruit and has no pocket in the flesh beneath the gum.

A second type appears about the time the pit begins to harden at the tip or a little before this time. This type always occurs on the ventral suture, although the point of appearance may be any place on the suture from the distal to the stem end. The gummy mass is large in size, globular, and rather smooth in outline. A pocket does not occur beneath the point of appearance of the gum. Instead, the flesh and pit seem to be split and a continuous mass of gum extends into the endocarp and entirely fills the cavity of the pit. A large proportion of this type of gummy fruits falls within a week or 10 days after the gum makes its appearance.

The third type of gumming begins to appear about 2 weeks after the entrance of the peach into the second growth phase, that is after the pit begins to harden at the tip. The number of gummy fruits of this type increases very rapidly, so that 80 to 90 per cent of the total number of gummy fruits of this type has made its appearance by the end of the third week after the first gumming has appeared. The gum of this type is twisting in nature, and small in size as compared to the second type. It occurs on the distal end or dorsal side near the distal end and is always accompanied by a pocket in the flesh. It is this type of gum which causes the heavy losses at harvest time.

No organism has so far been associated with this gumming.

Studies on the Influence of Soil Moisture on Growth of Fruit and Stomatal Behavior of Elberta Peaches

By F. P. Cullinan, and J. H. Weinberger, *U. S. Department of Agriculture, Washington, D. C.*

DURING the season of 1932 studies were undertaken to determine the effect of soil moisture content on the growth rate and final development of peach fruits. Studies made during the previous season on the growth rate of fruit had suggested the importance of an adequate moisture supply, particularly during the final swell. (3).

Some Elberta peach trees, 21 years of age, growing in an orchard of the University of Maryland at College Park, were selected for these experiments. The soil is a sandy loam with a moisture holding capacity of about 15 per cent in the upper 3 feet, and with a permanent wilting percentage in the same soil area of 6 per cent. Two plots of trees were used, namely, where the soil was kept dry by excluding the rainfall during the season, and where the trees were grown under normal orchard conditions, supplementing the rainfall with water added to the soil when the moisture content approached the wilting percentage. The soil in the dry plot was covered with a waterproof paper, placed tightly around the trunks of the trees and extending 20 feet on either side. Six trees in a single row were used, and the paper was applied on May 20, about 4 weeks after blossoming. The trees in the dry plot were separated from the normal one by two intervening rows. All trees received a spring application of nitrate of soda.

After sufficient growth of tree and fruit had been made to give an idea of uniformity, four trees were selected for fruit measurements on the dry plot and two on the normal. Fruits of approximately the same initial size on branches of uniform vigor well distributed about the tree were chosen for daily measurements and thinned to a 40-leaf-to-fruit ratio. The same ratio was maintained on the tree as a whole. The thinning was done on May 21.

Soil samples of 1-, 2-, and 3-foot depths were taken at weekly intervals and dried for 24 hours at a temperature of 100 degrees. The permanent wilting percentage of the soil was determined by growing sunflower plants in closed containers.

As an index of leaf function, observations and counts were made at intervals during the season on the number of stomata open on representative leaves taken from trees on the two plots. The method used was to strip off a piece of the epidermis from the lower side of the leaf, place it under a microscope and count the number of open and closed stomata in a field of 50. Four to 5 leaves from each plot were observed in a single 15-minute reading.

It was possible, through the methods used, to bring about differences in the soil moisture content of the two plots. The amount in the first 2 feet of soil on the dry plot (Fig. 1) showed a steady

decrease during the period of observation, from May 21 to the date of fruit harvest, August 29. Before the paper was applied spring rains had been frequent and the moisture content was near the field capacity. The reduction of moisture in the soil under the paper was naturally slow. In the 25-day period from May 21 to June 15,

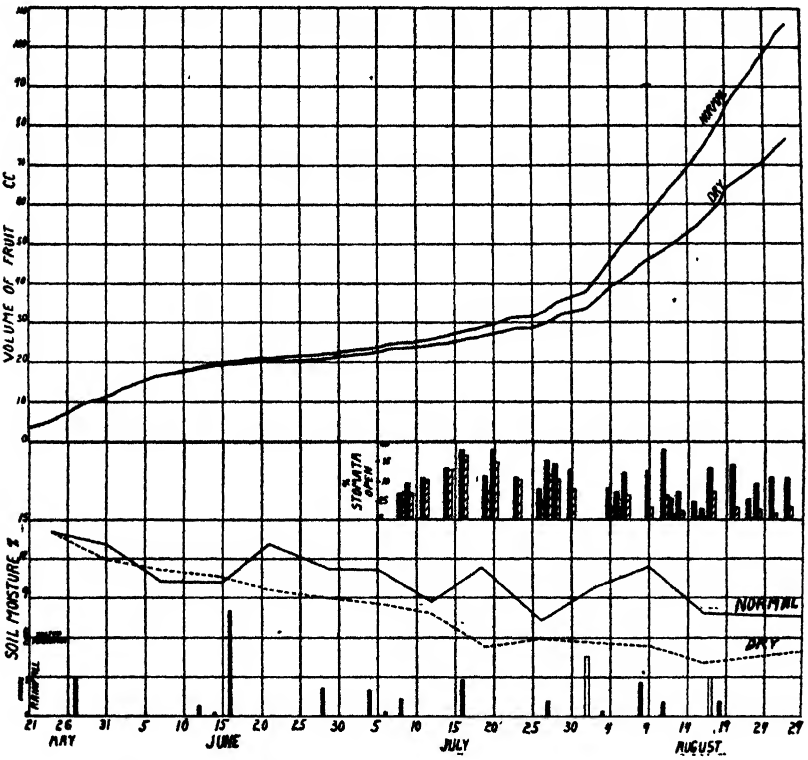

FIG. 1. The growth rate of fruit calculated on a volume basis and the stomatal behavior of the leaves is shown in relation to moisture content of the first 2 feet of soil. The unshaded bars under "Rainfall" show the amount of water added to the normal trees on those dates. The shaded bars under "Stomata" represent the normal, and the cross-hatched bars, the dry plot.

there was little difference in the amount of moisture in the dry and normal plots. However, on June 16, a 2.65-inch rain saturated the first 2 feet of soil in the normal plot but had no effect on the moisture content of the dry plot. This marked the beginning of the divergence in soil moisture between the two plots. By July 18 the dry plot was below the wilting percentage and remained below that point during the remainder of the season of fruit development. The normal plot showed the usual fluctuations in moisture incident to seasonal rainfall and the amount of water added to keep the soil at all times well above the wilting percentage.

The data showing the growth of the fruit calculated to a volume basis from the daily circumference measurements are shown graphically in Fig. 1. The general slope of the curve on the seasonal growth rate follows that which has been observed and described by other workers. The daily volume increase appears to be closely associated with the soil moisture content of the normal and dry plots. During the period of initial growth increase of the young fruit, between May 21 and June 16, there is little difference in the average size of the peaches on the two plots. Little difference in moisture content was noted during this period. Between June 16 and August 1, or the second period when the fruit develops slowly, there is also little difference in the growth rate of the fruit. It will be noted, however, that there is an increasing gradient in volume increase in the normal plot over the dry plot. It was during the latter part of this period that the moisture content of the dry plot was below the wilting percentage. The third and final period of fruit development, August 1 to August 27, is a period of rapid development. The fruits on the normal plot increased in volume showing an average daily gain of 2.61 cc as compared with 1.65 cc for the dry plot. (Table I).

TABLE I—Increase in Volume of Fruits on Normal and Dry Plots

Period	Dry Plot (cc)	Average per Day (cc)	Normal (cc)	Average per Day (cc)
May 21	3.5	—	3.5	—
May 21–June 16	16.0	.61	16.7	.64
June 17–Aug. 1	14.4	.31	17.8	.39
Aug. 2–Aug. 27	33.9	1.65	68.0	2.61

It is quite apparent that during the final period of development, the fruit on the dry plot failed to maintain a comparable growth rate with the fruit on the normal plot. During this last swell the moisture content of the dry plot was below the wilting percentage and the final average volume of 77 cc (2 in.) for this plot as contrasted with 106 cc (2¼ in.) for the normal plot is doubtless to be attributed to the low moisture supply obtaining in the first 2 feet of soil. It is interesting to note that the marked increase in growth for the final period began on August 1 for both plots. This date happens to coincide with the date of application of 1.5 inches of water to the normal plot. This in part might account for the noticeable swelling of the fruit on this plot but it does not explain why the dry plot which has been below the wilting percentage should also manifest a similar growth increase at this time.

Difference in moisture content, such as obtained on these plots during the season might also be expected to affect leaf function. Stomatal behavior has been used as an index of the functional activities of the leaf. Samples of leaves were taken over a period of 29 days, between July 8 and the date of harvest. The daily ob-

servational period varied from 2 to 10 hours, depending upon the length of time the stomata were found open.

It was observed that during the period from July 8 to July 16, stomata were found to remain open for about the same length of time on the two plots (Fig. 1). It will be recalled that the moisture content of the dry plot dropped below the wilting percentage around July 18. After July 16 the difference in length of time during which stomata remained open on the two plots was more noticeable. After August 1, which is the date of the beginning of the final swell, the percentage of stomata open was at no time equal to the normal plot. During the month there were many days when they were open for only a few hours in the morning. It was also noted that the period of time during which stomata were open on the normal plot was also shortened during August, even though the moisture was above the wilting percentage. Thus, during late August, with relatively high temperatures and low humidity, the stomata of the normal trees were open from 5 to 6 hours in the forenoon and then closed down, while on the trees in the dry plots they were open only a few hours in the morning. While stomatal behavior seems to be closely associated with soil moisture content as determined in the first 2 feet of soil, it is not to be inferred that soil moisture alone is the limiting factor in stomatal behavior. Humidity is also a factor. Thus, on August 9 it was found that an average of 63 per cent of the stomata were open on the normal plot during a 5½-hour period, while only 17 per cent were open during the same length of time on the dry plot. On August 11, 2 days later following a rain, 90 per cent of the stomata were open on the normal plot and 32 per cent on the dry plot during a 7-hour period of observation.

From the growth measurements made during this study it was apparent that any reduction in daily volume increase during the season was reflected in the final size of the fruit. The growth curve of the fruit indicates that moisture was a limiting factor even before the date of the final swell. Whether or not the volume difference in size of fruit between the wet and dry plot would have been more pronounced, had the moisture in the dry plot been below the wilting percentage early in the season it is difficult to state. The trees in the dry plot did not reduce the water in the first 2 feet of soil below the wilting percentage until about July 15. Had surface evaporation taken place, this reduction in moisture content would have been more rapid. Hendrickson and Veihmeyer (1) report that mature peach trees under California conditions, growing in a sandy soil, were able to reduce the soil moisture content, at least in the principal root zone, from the maximum field capacity down to the wilting coefficient in 1 to 3 weeks and were able to reduce it in 3 to 4 weeks in a clay loam soil. Jones (2) working with a coarse sand in North Carolina and using mulch paper to keep off the rainfall was able to lower the moisture below the wilting percentage in the first foot of soil in 3 weeks.

TABLE II—Per cent of Stomata Open on Leaves Collected from Wet and Dry Plots During the Daily Period of Observation

Date	Period of Observation	Number Hours	Per cent Stomata Open	
			Normal Plot	Dry Plot
	A.M. P.M.			
July 8	10:30–12:00	1.50	33	34
9	8:45– 4:45	8.00	47	33
11	10:30– 4:30	6.00	53	50
14	10:15– 2:30	4.25	65	63
16	10:15– 4:45	6.50	89	82
19	9:00– 4:30	7.50	55	39
20	10:15– 4:45	6.50	87	74
23	9:45– 4:15	6.50	54	50
26	2:30– 4:30	2.00	39	18
27	10:00– 3:30	5.50	75	57
28	9:15– 4:15	7.00	71	52
30	9:00–12:00	3.00	64	38
Aug. 4	12:45– 4:10	3.75	39	14
5	9:30– 4:00	6.50	35	15
6	4:45– 4:30	11.75	59	32
9	10:00– 3:30	5.30	63	17
11	9:00– 4:30	7.50	90	32
12	1:15– 4:15	3.00	27	8
13	11:30– 4:30	5.00	36	11
15	10:00– 4:00	6.00	24	7
16	12:30– 2:45	2.25	15	5
17	6:00–12:00	6.00	67	36
20	9:00– 4:30	7.50	70	13
22	1:00– 4:30	3.50	26	3
23	6:00– 3:00	9.00	46	15
25	8:30– 3:30	7.00	55	10
27	6:00– 4:00	10.00	54	18
31	8:00–10:00	2.00	28	8
Sept. 10	8:30–21:00	3.50	60	11

The type of soil and depth of root system are factors to be considered. On the type of soil used in these experiments, 90 per cent of the roots were in the first 2 feet. Moisture in the third foot was close to the wilting percentage on the dry plot during most of the month of August. Evidently, there was sufficient moisture available to some of the roots on this plot, as the trees did not show permanent wilting.

In the peach growing sections of the eastern United States where irrigation is not a common practice, 2 or 3 weeks of dry, hot weather during the period of the final swell may markedly affect the size. This change in the moisture content of the soil is well illustrated by data on soil moisture on the normal plot. On July 19 the moisture content of the normal plot in the first foot following a 0.9-inch rain on July 16, was 11.54 per cent; for the second foot, 11.13 per cent; and for the third foot, 9.14 per cent. One week later the moisture percentage was 4.95 or below the wilting percentage for the first foot, 9.57 for the second foot, and 7.95 for the third. Similarly, on August 9, following an 0.89-inch rain the moisture in the first, second, and third foot areas was 12.74, 10.01,

and 10.00 per cent, respectively. One week later, the moisture content of these areas was 6.19, 9.64, and 6.98 per cent. This was during the period when the fruits were making the most rapid growth and were depleting the soil moisture in the first 3 feet of soil very rapidly. Any lowering of the available moisture supply in the principal root zone would be expected to influence leaf activity. On the dry plots where the leaf ratio on ringed branches was adjusted to 40 leaves the final size of fruits was 90.8 cc as contrasted with 119 cc on ringed branches of the normal plot. With reduced leaf function early in the season and the resulting decrease in food manufacture, it is probable that final size would also be affected, even though moisture conditions were favorable for growth during the final swell.

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Further Observations on Influence of Leaf Area on Fruit Growth and Quality in the Peach[1,2]

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FRUIT development and quality has been found by many investigators to be markedly influenced by the load of fruit borne on a tree. A study of this relation in the peach was started in the Sandhill section of North Carolina in 1931 (1). The investigation was based on observations of growth and chemical composition of fruit from ringed branches having different leaf-to-fruit ratios. This paper is a report of similar experiments continued in 1932 in which the Hiley variety was used.

TABLE I—The Relation of Relative Leaf Area to Fruit Size (Expressed as Fruit Volume in cc)

Date	Ringed Branch Leaf-to-fruit Ratio					Unringed Branch
	10/1	20/1	30/1	45/1	60/1	
May 25	14.3	15.0	15.7	16.1	15.1	15.4
June 14	19.6	23.1	26.4	27.0	25.7	21.3
23	23.1	31.4	35.4	36.2	36.2	26.4
29	27.0	39.7	46.3	49.4	47.3	32.2
July 2	29.9	47.3	54.8	57.0	55.9	36.2
5	33.0	53.6	62.9	67.9	65.3	41.5
8	38.9	62.9	73.1	80.0	75.9	48.4
11	40.6	67.9	78.7	85.9	80.0	53.6
13	42.5	69.2	81.5	87.5	83.0	55.9
15	43.4	70.5	83.0	88.9	84.4	58.1
18	44.4	73.1	85.9	90.5	85.9	61.7
20	45.3	73.1	87.5	90.5	85.9	62.9
22	44.4	73.1	87.5	—	85.9	64.1
25	44.4	73.1	88.9	—	—	66.6
27	46.3	74.5	88.9	—	—	67.9
29	47.3	74.5	88.9	—	—	70.5
Aug. 1	49.4	—	88.9	—	—	71.8
3	50.4	—	—	—	—	73.1
5	50.4	—	—	—	—	—
6	50.4	—	—	—	—	—
Increase in fruit volume from date of ringing to harvest	36.1	59.5	73.2	74.4	70.8	57.7
Number of fruit measured	272	125	87	74	52	218

The trees used were about 6 years old and were small, as soil fertility and cultural practices of this region do not favor the formation of large peach trees. Five reasonably uniform trees were selected from the same part of the orchard. Six branches comparable as

[1]This is a report of a cooperative project between North Carolina Agricultural Experiment Station and the Division of Horticultural Crops and Diseases, U. S. D. A.

[2]Published with the approval of the Director of the N. C. Agricultural Experiment Station as Research Paper No. 62.

to size and position were chosen in each tree. Five of the branches were ringed and leaf-to-fruit ratios of 10/1, 20/1, 30/1, 45/1 and 60/1 were established. The sixth branch was left unringed, as a check, and the fruit was thinned to a degree comparable to that portion of the tree not under this experiment. The experimental branches each represented about $\frac{1}{12}$ to $\frac{1}{16}$ the total tree.

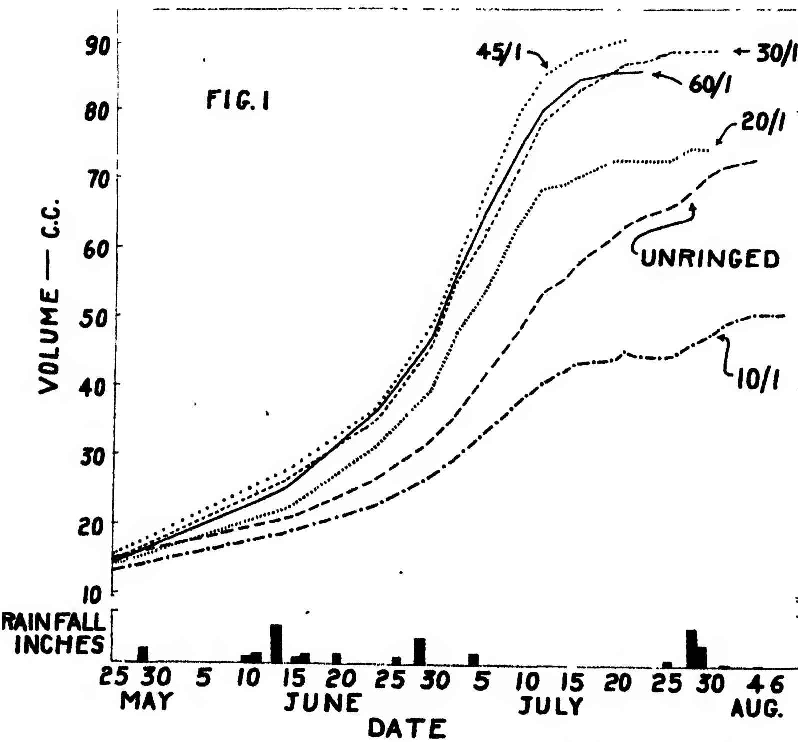

FIG. 1. The Seasonal Development of Fruit as Influenced by Relative Leaf Area on Ringed and Unringed Branches.

The fruits on the different branches were individually tagged to insure accuracy in the measurements. Fruit circumference measurements were taken at intervals of 10 days the first month and at intervals of 2 or 3 days the remainder of the growing season. Leaf counts were made every 2 weeks in order to maintain the desired leaf-to-fruit ratios.

As the branches were chosen to be comparable in size it necessarily followed that the number of peaches measured under the different leaf-to-fruit ratios decreased correspondingly as the ratio increased. A record of the total number of fruits measured throughout the season under each ratio is given in Table I.

Fruit volume was computed from the fruit circumference measurements, assuming that the peach was a sphere at all times.

Table I and Fig. 1 show the rate of growth of the fruit from the branches having different leaf-to-fruit ratios throughout the period from date of ringing to harvest. Fig. 1 also indicates the dates and amounts of precipitation during the same period.

The data in Table I and Fig. 1 show that as the leaf-to-fruit ratio increased from 10/1 to 45/1 there was an increase in the rate of growth of the fruit but that the fruit on the 60/1 branches developed at a rate slower than that on the 45/1 branches. Furthermore, the data on increase in fruit volume from date of ringing to date of harvest, show the same condition.

TABLE II—THE EFFECT OF RELATIVE LEAF AREA ON THE RELATIVE DATE ON WHICH FRUIT MATURED (EXPRESSED AS PERCENTAGE FRUIT REMAINING ON TREES ON GIVEN DAYS)

Days after Harvest Began	Ringed Branch Leaf-to-fruit Ratio					Unringed Branch
	10/1	20/1	30/1	45/1	60/1	
1	100	93.2	88.8	90.9	77.0	100
2	100	93.2	88.0	90.9	77.0	100
3	100	93.2	85.1	79.6	69.9	100
4	100	93.2	83.8	79.6	69.9	100
5	100	79.4	67.6	60.4	67.0	100
6	99.7	78.4	67.6	60.4	67.0	100
7	99.2	65.1	61.6	45.1	47.4	98.1
8	99.2	65.1	61.6	36.8	47.4	98.1
9	98.0	55.3	50.5	17.9	27.2	95.5
10	96.8	47.1	43.6	13.1	22.2	93.7
11	96.8	33.0	42.3	13.1	14.7	93.3
12	95.3	26.9	33.9	6.4	12.5	89.0
13	91.2	18.0	19.4	2.7	3.1	82.9
14	89.9	18.0	16.8	0.0	0.0	82.5
15	76.7	9.8	7.1	—	—	68.7
16	76.1	9.8	7.1	—	—	67.8
17	67.0	2.9	7.1	—	—	53.1
18	64.4	2.9	7.1	—	—	52.7
19	63.1	2.9	7.1	—	—	50.2
20	45.5	2.9	4.7	—	—	33.0
21	44.4	2.9	4.7	—	—	33.0
22	25.5	0.0	3.5	—	—	21.0
23	25.5	—	3.5	—	—	21.0
24	22.0	—	0.0	—	—	15.3
25	22.0	—	—	—	—	15.3
26	16.5	—	—	—	—	7.5
27	16.5	—	—	—	—	7.5
28	4.7	—	—	—	—	0.0
29	0.0	—	—	—	—	—
30	—	—	—	—	—	—

This tendency of the 60/1 branches to produce fruit smaller than the 45/1 branch was very evident throughout the experiment. By plotting the data for individual trees it was indicated that this was generally true for each tree.

The date of fruit maturity appeared to be definitely affected by the relative number of leaves per fruit on the branches. At the

time of harvest the first fruit to ripen was that from the high leaf-to-fruit ratio branches, while the fruit which matured latest was that from the ringed branches, with 10 leaves per fruit, as shown by the summary of the picking records presented in Table II.

The data presented in Table II indicate that all the leaf-to-fruit ratios on the ringed branches other than 10/1 favored a definite hastening of maturity as compared with the unringed or check branches.

Reference was made earlier to the fact that a severe moisture deficiency developed during the latter portion of the fruit growing season. This moisture shortage prolonged the picking season of the commercial crop of the Hiley variety over about twice the usual number of days. Accordingly, the differences in the dates of fruit maturity from the different branches as shown in Table II are somewhat exaggerated this season.

TABLE III—The Relation of Relative Leaf Area to the Chemical Composition of Fruits (Chemical Calculations on Fresh Weight Basis)

Leaf-to-fruit Ratio	Total Solids	Alcohol-insoluble Fraction	Alcohol-soluble Fraction	Total Sugars Expressed as Glucose	Acidity as Citric Acid
Ringed Branches					
10/1	14.84	2.66	12.19	9.45	0.48
20/1	16.46	2.51	13.95	10.46	0.56
30/1	17.14	2.63	14.51	10.76	0.64
45/1	17.86	2.68	15.18	11.16	0.61
60/1	17.83	2.71	15.10	11.18	0.67
Unringed Branch	16.08	2.42	13.65	10.29	0.55

As the fruit was harvested a portion of it was immediately preserved for chemical analyses. Fruit from each branch was preserved separately and the results of the chemical analyses represents a summarization of the individual branch samplings.

The fruit was harvested at all times at as nearly the same stage of maturity as was possible to determine in the orchard. Because color of the mature fruit varied markedly on branches having different leaf-to-fruit ratios, color was considered unreliable as a criterion of ripeness. The most satisfactory guide for fruit picking was found to be a combination of change in ground color and ease of separation of the fruit from the stem.

All fruit was pressure tested in the laboratory and only that averaging from 2½ to 5 lbs. pressure per punch was chemically sampled. Table III presents the data collected by the chemical analyses of 56 samples taken from the 30 different branches.

Chemical analyses indicated a marked tendency for an increase in percentage of total solids, alcohol-soluble fraction, total sugars and titratable acidity, as leaf-to-fruit ratio on the ringed branches increased. The concentration of these different fractions for fruit from the unringed branches was found to be consistently intermediate between those values found for that from the 10/1 and

20/1 ratios on the ringed branches. The tendency for the alcohol-insoluble fraction to increase as the number of leaves per fruit was increased appear to be very slight.

In comparing fruit flavor it was found that in general the fruit from the 10/1 branches was always flat, insipid and disagreeable. The fruit from all the other branches in this experiment was either of a uniformly good flavor or was bitter. Bitterness was always associated with the condition of split pits in fruit from ringed branches. Split-pit fruits from unringed branches were not bitter.

With reference to color it was found that on the ringed branches the 10/1 ratios produced fruit intensely colored but of a dingy hue. The 20/1 and 30/1 ratios produced fruit very normal as to coloring. The 45/1 and 60/1 branches were quite devoid of brightly colored areas. The red color present was a small stippling on a pale ground-color. The flesh of the fruit from the 10/1 branches was generally green while that of the 45/1 or 60/1 branches was often bright red to the pit.

Summarization of this study shows that an increase in leaf-to-fruit ratio on ringed branches of Hiley results in (1) increasingly larger fruit on from 10/1 to 45/1 branches, though not in proportion as the relative leaf-area-increases, and smaller fruit on 60/1 than on 45/1 branches; (2) an increase in percentages of total solids, total sugars, acidity, alcohol-soluble fraction, and possibly alcohol-insoluble fraction; (3) a hastened date of fruit maturity; (4) change of fruit color from abnormally intense and dingy on 10/1 to decidedly pale on 45/1 and 60/1; (5) change in fruit flavor from insipid on 10/1 to very good on other ratios. Fruit from unringed branches was intermediate between that from the 10/1 and 20/1 ringed branches with respect to fruit growth and chemical fractions studied.

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The Effect of Irrigation on the Quality of Prunes

By A. H. HENDRICKSON and F. J. VEIHMEYER, *University of California, Davis, Calif.*

SOIL moisture conditions during the growing season have long been popularly held responsible for certain qualities in fresh, canned, and dried fruits. Usually, the defects in any variety are thought to be accentuated by irrigation, while unirrigated fruits are supposed to have merits not possessed by those watered artificially. How available soil moisture maintained by irrigation brings about deleterious results, while that maintained by rain does not, has never been satisfactorily explained.

Results, reported at previous meetings of this society, (1, 2) showed that neither the canning quality of clingstone peaches nor the keeping quality of Thompson Seedless grapes was adversely affected by the maintenance of available soil moisture throughout the growing season by irrigation. Recent results with berries reported by the Oregon station substantiate these results (3).

Experimental results obtained during the past 3 years with French (Agen) prunes throw light on the effect of irrigation on the quality of the dried product. The effect of irrigation on yields and size of fruit will be discussed in a future paper. Five mature trees, growing in a Yolo sandy loam soil at Davis, surrounded by guard trees constituted a plot. The irrigated plots are laid out in duplicate, while the unirrigated plots are in quadruplicate. Four treatments, including the unirrigated plots were used. The trees were irrigated by the basin method and the soil was wetted to a depth of 6 feet at each irrigation. The soil in treatment A was not allowed to reach the permanent wilting percentage at any time. Three irrigations were applied before the crop was harvested. Treatment B was given the same irrigation as A until the first week in July after which no water was applied. The trees in this treatment usually wilted 2 or 3 weeks before harvest time. In treatment C no water was added to the soil in the early part of the season. The trees in this plot usually reduced the soil moisture to the permanent wilting percentage about the first week in July. They were allowed to remain wilted for a week or two and then irrigated. Available soil moisture was maintained in this plot through the remainder of the growing season. In other words, treatment B was irrigated the same as A during the first part of the season and C was irrigated the same as A during the last part of the season. In treatment D (unirrigated) the trees started the season with the soil moisture resulting from the winter rains, but no water was applied during the growing season. The trees in this treatment, like those in treatment C, usually wilted about the first week in July and remained wilted the rest of the season.

The soil moisture records for treatment A and D for 1930 are

given in Fig. 1. It will be noted that the trees in treatment A had available moisture throughout the growing season, while those in treatment D had exhausted the available soil moisture about the first week in July. The foliage on the trees in treatment A remained

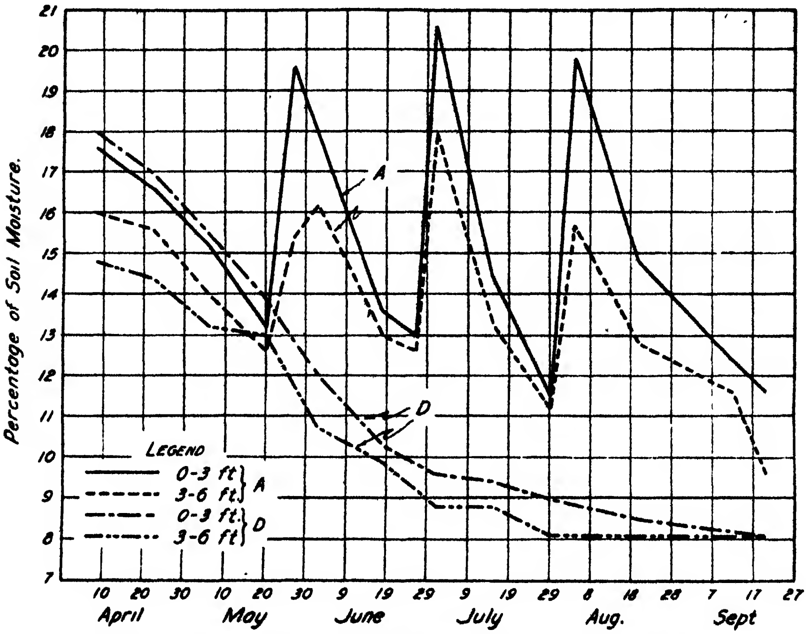

FIG. 1. Soil-moisture conditions of treatments A and D in a French (Agen) prune orchard at Davis, California, 1930. The soil-moisture conditions of treatments B and C are described in the text. The permanent wilting percentage of the top 3 feet of soil is 10.7 per cent, that of the second 3 feet, 8.1 per cent. The samples of the top 3 feet included the surface soil that was dried by direct evaporation.

green and turgid, while that on the trees in treatment D wilted and began to drop before the crop was harvested. The records for treatments B and C are omitted for lack of space. The moisture conditions in these treatments are described in the general explanation in the text.

Specific gravity determinations, sugar contents, and drying ratios of the dried prunes are given in Table I. In a recent publication Nichols and Reed (4) have called attention to the fact that specific gravity of prunes may be used as a measure of quality. In general, those prunes having light amber colored flesh, free from gas pockets, have a higher specific gravity than those with dark flesh containing one or more gas pockets. It is evident from the data that no consistent differences in quality of prunes were found that could be attributed to the irrigation treatment. The comparatively slight differences found, varied in an indefinite manner. Further-

more, no consistent differences in color or general appearance were observed in the fruit from the various treatments.

TABLE I—SPECIFIC GRAVITIES, SUGAR CONTENTS, AND DRYING RATIOS OF FRENCH PRUNES

Treatment	Specific Gravity			Per cent total sugar, on fresh Weight Basis			Drying Ratio		
	1930	1931	1932	1930	1931	1932	1930	1931	1932
A	1.248	1.193	1.067	11.86	13.80	11.78	3.3	2.5	2.9
B	1.251	1.174	1.096	11.67	13.84	12.06	3.0	1.8	2.8
C	1.208	1.176	1.090	12.00	14.26	11.50	2.9	3.0	3.0
D	1.195	1.187	1.095	11.63	13.71	11.60	3.0	2.3	2.6

Slight variation was found in quality of the fruit from year to year as shown by specific gravity determinations. In general, the poorest quality was obtained in 1932 and the best in 1930. Apparently the amount of fruit produced did not exercise much influence on the quality. In 1930 the average production of all treatments was 12 tons of fresh fruit per acre; in 1931, 0.5 tons; and in 1932, 6 tons. Thus, with the extremely heavy crop in 1930 the quality was better than was the case with either the very light crop of 1931 or the moderate crop of 1932.

The percentages of total sugars showed no consistent differences that could be attributed to the irrigation treatments. In 1931, when the crop was exceptionally light, the percentages of sugars were consistently higher than in either 1930 or 1932, and these differences seemed to be reflected in the drying ratios.

In spite of popular opinions to the contrary, no consistent differences could be found in the ratios of the weights of fresh to dry fruit. The drying ratios given in the table are calculated to the same moisture percentage, because the various lots of fruit have slightly different moisture contents as they are taken from the dehydrater. The differences in drying ratios shown in the table are probably due to the relative amount of drying to which the prunes were subjected before picking. Some drying takes place on the trees, during certain seasons, before the fruit drops, and some drying occurs while the fruit is on the ground before it is picked up.

It is evident from these data that neither the specific gravities, sugar contents, nor drying ratios of French prunes grown on a Yolo sandy loam soil at Davis, California, were affected by irrigation treatment.

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Arsenical Injury of the Peach and Some Results of Studies on Its Control

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DESPITE precautions proposed for the control of acid lead-arsenate injury, much damage to foliage, twig, bud, and fruit occurs every year in North Carolina. It is important that the arsenate injury be adequately controlled, since it possesses under certain conditions confusing and indefinite similarity to the spot and cankers caused by *Bacterium pruni.* The time of application and the source of water seem to exert some influence on the amount and severeness of injury even when the same grade and different makes of acid lead-arsenate are used. There is considerable variation in the reaction of different varieties to lead-arsenate injury. Certain germicidal and fungicidal chemicals accelerate arsenate injury and others suppress it, though somewhat erratically. During the course of studies on bacterial spot over a period of 4 years, notes of some significance on reduction of lead-arsenate injury were obtained.

The varieties under observation were Early Rose, Red Bird, Hiley Belle, Georgia Belle, Elberta and J. H. Hale. The studies were conducted in the Sand Hill area where the soil is mostly low in plant nutrients and is of the deep phase, and also in the Piedmont on Cecil sandy loam. Injury of the most severe type occurred on both soil types.

The foliage, buds, and twigs of Early Rose, Red Bird, Hiley Belle, and Georgia Belle varieties were injured more severely by early spray applications than were Elberta and Hale varieties, even when the sprays were timed for petal fall and shuck stages. The leaves are generally well exposed by this time. Both of the first two sprays frequently result in heavy injury. Cankering in the crotches and just beneath the buds is very conspicuous, finally resulting in heavy defoliation of the first leaves. The leaf margins are most prominently injured, but spots always occur to some extent in the intercostal areas. Leaf injury becomes more severe as the season advances, and often is most conspicuous during the late summer and early autumn period.

Fruit injury occurs mostly on the stem end and on the sun-exposed sides. It is more severe on the Elberta and Hale varieties than on earlier ones. Injury of immature fruit is rarely observed. The injury advances with maturity, finally causing large dark colored spots with purple to red borders and sometimes extending in depth to the seed. More than 50 per cent of the fruit in many orchards is rendered worthless in this manner.

There is a relation between character of growth and severeness of injury. Trees injured by such root diseases as those caused by *Armillaria mellea, Bacterium tumefaciens,* and *Caconema radicicola,*

which always definitely stunted the growth, show much leaf, bud, and twig resistance to lead-arsenate injury. The vigorous terminals of healthy trees, growing adjacent to diseased trees and receiving the same spray, are more often severely injured. On the other hand, the fruit on the diseased trees is much more severely injured than is fruit on the healthy trees. This phenomenon could probably be explained by the absence of sufficient foliage on the diseased trees to protect the fruit from the light rays that combine with the lead-arsenate to destroy the exposed tissues.

The seasonal conditions are a deciding factor in the amount and severeness of lead-arsenate injury in North Carolina. Heavy persistent humidity at any period during the growing season is favorable for the development of lead-arsenate injury. The most severe damage develops when rainy weather occurs early in the season, since defoliation exposes the fruit. Bud, fruit, and twig damage may often develop prominently when rains occur 2 to 4 weeks previous to ripening and when drought periods predominate throughout most of the spray period. Hypertrophic areas continue to develop on the injured twigs even in late autumn. It would seem advisable to lower the lead-arsenate strength by ⅓ or even ½ for late applications in drought seasons when it is reasonably certain that the previous applications are durable, and especially when spraying is done well.

Emulsified phenol, emulsified cresol, potassium permanganate, and colloidal copper sprays impregnated with acid lead-arsenate stimulate injury. Potassium permanganate used with lead-arsenate resulted in 100 per cent leaf and fruit injury during the 1931 season.

The coarse hydrated limes which were most extensively used with lead-arsenate in North Carolina previous to 1932, were less effective in suppressing injury than the chemical and finishing hydrated limes. Even with the use of 5 pounds of the better limes to 1 pound of lead-arsenate in 50 gallons of water considerable injury has occurred. Contrary to the tests of some investigators, increasing the lime to 10, 20, and even 50 pounds to 50 gallons of water to which is added 1 pound of powdered lead-arsenate reduced injury. Repeated field tests during the past 3 years have shown complete inhibiting of injury where 50 pounds of finishing hydrated lime, which contains some magnesium, and chemical hydrated lime were used in 50 gallons of water. This amount practically white washes the tree, and when potash fish oil soap is used in the mixture it is very durable. Besides the cost involved in using this amount of lime, the large amount of residue left on the fruit at harvest is certain to be objectionable. However, the possible germicidal, fungicidal, and insect-repelling qualities of the lime used in such large amounts is worthy of study. The high alkalinity does not injure the plant in any way. Trees sprayed with the concentrated lime have held their foliage on fruit-bud wood much

longer than any other treated or untreated trees. However, effects in this way from changes in soil reaction have not been studied.

Zinc sulfate with sulfur, lead-arsenate, and lime has greatly lowered the injury during the early part of the season, even when used at the rate of 3 pounds in 50 gallons of mixture. This amount has given equally as much reduction of injury as have larger amounts of 4, 8, 10, and 12 pounds. This chemical seems to delay more than control the injury, since heavy damage on fruit and even leaves often occurs just before harvest and on leaves and twigs during the autumn season, regardless of the addition of zinc sulfate. In some tests the late injury has been equally as severe as on trees that were not sprayed with the zinc sulfate. The type of sulfurs used has not shown a very marked difference in varying the lead-arsenate injury. The use of zinc sulfate in the first two sprays after the foliage appears is advisable in areas where injury occurs constantly.

Factors Affecting the Breaking Strength of Apple Tree Crotches

By L. H. MacDaniels, *Cornell University, Ithaca, N. Y.*

Abstract

EXAMINATION of 20-year-old trees showed that bark inclusions, sufficient to cause serious weakness, were present in more than half the primary crotches of the varieties Northern Spy, Wealthy, Twenty Ounce, and Baldwin. The crotches of McIntosh and Rhode Island Greening were practically free from inclusions. The average angle of crotches with inclusions was 25 degrees and the maximum 40 degrees.

Breaking tests on 225 crotches from the varieties Wealthy, Twenty Ounce, and York Imperial, indicate that the relative size of the two crotch arms is a very important factor in breaking strength, the weight required to break any given crotch increasing directly with the increase in the size of the larger arm compared with the smaller. The data do not indicate that the crotch angle is of great importance if there are no bark inclusions. More than two side branches coming off the trunk at about the same level are likely to make a complicated and weak crotch structure. Better structure is secured when only a single main side branch is attached to the branch at any one level.

Measuring Apple Color With a Disc Colorimeter

By A. L. SCHRADER and J. H. BEAUMONT, *University of Maryland, College Park, Md.*

THE purpose of this paper is to present the possibilities of the disc colorimeter as an aid in solving some of the various problems in which the color of apples must be evaluated. At Maryland, in studies of factors influencing red color of apples, the difficulties attending the measurement of quality of red and ground color, the percentage of red color, and especially seasonal comparisons of color as affected by various treatments, have been constantly apparent. Descriptions based on common color terminology were quite inadequate, while percentage of red color at best could only be approximated by estimates based on the grouping of apples in rough color ranges. The disc colorimeter, as recently perfected, seems to offer a means of detecting differences in quality and percentage of color which would not otherwise be shown, or if apparent, could not be accurately evaluated or described.

THE DISC COLORIMETER

Dorothy Nickersen, (1) (2), gives a detailed description of the newer model of the disc colorimeter, as well as some results and applications with agricultural products. In brief, the old system of spinning Munsell color discs to match the color of a sample is so modified that the discs remain stationary while a revolving wedge mixes the colors so that they appear as a uniform color in the lower half of a telescopic field. The upper half of the telescopic field is the projection of the light from the sample, also appearing as a uniform color regardless of the variegation in the color of the sample. Thus, by a series of lenses and prisms, neither the sample nor the color discs are seen directly in the eyepiece of the telescope, and the colors are quickly matched by adjusting the color discs as one views the two colors in the eyepiece. The sample field measured can be varied from approximately 1 to 15 inches in diameter.

The area of each disc used in matching a sample is recorded in per cent of the entire area and these readings are used to calculate, by formulae, numerical expressions of hue, value, and chroma, which are the psychological attributes of color. The calculations are based on the Munsell system of notation which expresses the chromatic hues of red, yellow, green, blue, purple and their intermediate hues in numerical terms from 0 to 100, thus red has a hue number of 5, yellow 25, green 45, blue 65, and purple 95. The complete notation is given as follows:

R	5	Y-GY	30	BG	55	PB-P	80
R-YR	10	GY	35	BG-B	60	P	85
YR	15	GY-G	40	B	65	P-RP	90
YR-Y	20	G	45	B-PB	70	RP	95
Y	25	G-BG	50	PB	75	RP-R	100

Any given chromatic hue may vary in value (also called brilliance) a low value designating a dark "shade" of the given hue and a high value meaning a light "shade." Thus, a dark red apple would have a low value compared with a light red apple of the same hue. Value is expressed in numerical terms from 1 to 10. Black (a non-chromatic hue) has a value of 0 while white has a value of 10.

A given chromatic hue also may vary in chroma from weak chroma to strong chroma which is numerically indicated by a range from 0 to 10 or above, depending on the hue. With red color of apples, a dull red has a weak chroma, so that variations in chroma of apples might be considered in terms of degree of dullness or brightness.

Thus, it can be seen that the description of any color in terms of its hue, value, and chroma, can be quantitatively expressed.

Measuring the Quality of Apple Color

Two methods of attack were used. First, the measurement of red and ground color on individual apples was attempted. The smallest field (less than 1 inch in diameter) was used and the quality of the green or red color on a limited area of the apple was measured. The second method involved the measurement of a "mosaic" sample which consisted of sixteen 7/8-inch squares of apple peel, one from each apple, fitted together in a "mosaic" to form one larger square about 3½ inches square. This sample, placed on a black background, was measured with a 4-inch field. The apples were drawn from sized and graded fruit representing different types of color.

One difficulty encountered in the first method was found in measuring apples of high chroma. A good match was not possible unless a narrow strip of gray paper was placed on the apple to act as a color mask in reducing the chroma. Another trouble was due to the gloss of the apple which produced high lights in the color field. This gloss was eliminated by patting the apple with a piece of velvet.

Results with Individual Apples

Stayman Winesap apples of a wide range in quality of red color from a deep red to a bronze red were obtained from various fertilizer plots for this study. Readings made with the disc colorimeter on the red side of 84 apples on November 17, showed a range in hue number from 2.93 to 9.90. Sixty of the same apples (not including the highly colored apples) measured on October 17, showed a range from 3.97 to 10.0. Thus, according to the Munsell system given previously, the hue of Stayman apples varied from a purplish-red to a red-yellow red.

The data in Table I derived from the individual readings, show some interesting relationships. The poorest quality of color found was in the immature sample A and is defined by a high hue number, low chroma, and high value. As the color quality of the apples increases (in descending order of the samples) the hue number decreases, the value decreases, and the chroma increases. Thus, hue is negatively correlated with chroma and positively correlated with value in the case of red color of Stayman Winesap.

TABLE I—Red Color of Stayman Apples, Determined by the Disc Colorimeter on Individual Apples. (Picked October 10, 1932)

Sample*	No. Apples	Red Color Range (Per cent)	Color Measurements, Oct. 27			Color Measurements, Nov. 17		
			Hue No.	Value	Chroma	Hue No.	Value	Chroma
A Nitrogen Immature	15	50	7.19	4.84	6.72	8.11	5.04	6.64
1-A Nitrogen	15	75	6.17	4.30	7.44	6.92	4.62	7.05
B Nitrogen Mature	15	50	5.52	4.18	8.45	6.24	4.63	8.21
D Nitrogen Mature	9	75–100	—	—	—	5.90	4.83	7.87
C Check	15	50	5.14	4.14	8.55	5.70	4.35	8.16
E Check	20	75–100	—	—	—	4.94	4.29	8.41

*Samples were taken from fertilizer plots, representing extremes. Devitalized check trees, receiving no nitrogen, bore 2 bushels per tree of fruit, coloring and maturing early. Vigorous trees, receiving 8 pounds of sodium nitrate per tree, bore 10 bushels of fruit, coloring and maturing late. Trees were about 18 years of age.

The data in Table I also indicate that the quality of the color changes during storage (common storage in this case) for during the period of October 27 to November 17, the hue number of the samples increased, the value increased, and the chroma decreased.

An apple with a low hue number, a low value, and a high chroma was found to be visually a bright, dark red apple, or an apple possessing a high quality of red color. However, correlating the visual conception of quality with the colorimeter readings will require further work on a classification of types of color for any given variety.

Results with "Mosaic" Samples

The data given in Table II were obtained from samples of Rome Beauty apples from nitrogen and no-nitrogen fertilizer plots. It will be noted that similar relationships between hue, value, and chroma were obtained as with Stayman Winesap in Table I. Also, it is clear that the size of apple and particularly percentage of the surface with red color both are related to the quality of the red color as expressed in the colorimeter readings. Apples with a smaller percentage of red color have measurably poorer quality of red color. The "mosaic" method offers a means of studying the quality of red color or ground color of apples with a great saving of time since it gives the average reading of 16 apples.

TABLE II—Red Color of Rome Beauty Apples Determined by the Disc Colorimeter on "Mosaic" Samples of the Fruit. (Picked November, 1932. Color Readings, November 2, 1932)

Sample		Color Measurements			
Treatment*	Diameter (Inches)	Red Color Range (Per cent)	Hue	Value	Chroma
Check	2¼–2½	25–50	R. 8.84	3.87	4.50
Nitrogen	2¾–3	25–50	R. 8.49	3.71	4.28
Nitrogen	2½–2¾	25–50	R. 8.00	3.68	4.78
Check	2½–2¾	25–50	R. 7.70	3.48	5.26
Nitrogen	2½–2¾	50–100	R. 6.44	3.23	5.16
Nitrogen	2¾–3	50–100	R. 6.44	3.20	5.16
Check	2¼–2½	50–100	R. 6.32	3.25	5.72
Check	3 and up	75–100	R. 5.82	3.07	5.22

*Check trees received no nitrogen, showed earlier coloring and maturity, and bore half as apples as nitrogen trees which received 10 pounds of sodium nitrate per tree.

Measuring the Percentage of Apple Color

In this study the largest field of the colorimeter (nearly 15 inches) was used. The apples from different fertilizer plots were sorted into grades according to the percentage of surface colored, as well as size. Each reading was made on approximately 30 to 50 apples and the sample area was composed of a mixture of red and green color. Such samples are termed "composite" samples. The data given in Table III represent the readings taken on the red side and on the green side of the same apples.

The data show that apples with 25 to 50 per cent red color have a consistently higher hue number than apples with 50 to 100 per cent red color. Within the samples with 50 to 100 per cent red color wide differences in hue number also occur, showing the possibilities of the colorimeter in defining more accurately differences in red color of apples that may be classed as having the same percentage of red color.

A part of the difference in color readings among apples of different per cent of red color is due to the difference in quality of red color which was noted in Tables I and II. Also differences in ground color, which were measured on the same samples, indicate that it contributes to the differences noted among the "composite" samples. However, the major portion of the difference is ascribable to the relative amount of the surface colored.

Conclusions

The disc colorimeter offers possibilities as a tool in defining differences in apple color in numerical terms. The preliminary data presented show that red color of apples is measured to a large extent in terms of hue, although chroma is of considerable importance and value, and also contributes a part in the definition. The quality of the red color, as well as ground color, so important in a commercial way, can be defined accurately in these terms.

TABLE III—Color of Rome Apples (Composite of Green and Red) Determined by the Disc Colorimeter on "Composite" Samples. (Rome Picked November, 1932. Color Readings, November 10, 1932)

Sample			Red Side			Green Side			Average		
Treatment	Diameter (Inches)	Red Color Range	Hue No.	Value	Chroma	Hue No.	Value	Chroma	Hue No.	Value	Chroma
Check......	2¼–2½	25–50	12.20	3.08	4.60	23.47	4.27	3.70	17.84	3.68	4.15
Nitrogen....	2¼–2½	25–50	11.90	3.30	3.82	23.47	4.33	3.04	17.68	3.82	3.43
			11.98	3.35	3.56	23.17	4.38	3.16	17.52	3.87	3.36
Nitrogen....	2¼–2½	25–50	11.86	3.29	3.44	22.89	4.41	3.28	17.38	3.85	3.36
Nitrogen....	2½–2¾	50–100	8.24	2.85	4.11						
			8.55	2.98	4.02	22.47	4.26	3.22	15.51	3.62	3.62
Nitrogen....	2¼–2½	50–100	6.51	2.60	4.54	20.36	4.14	3.74	13.44	3.37	3.88
									13.64	3.44	3.88
			6.98	2.73	4.24	20.29	4.14	3.52	13.62*	3.19	3.36
Check......	2¼–2½	50–100	5.76	2.54	4.72	12.11	3.63	4.06	8.94	3.09	4.39
Check.......	2½–2¾	50–100	4.86	2.59	5.38						
			5.00	2.68	5.04	8.00	4.41	3.78	6.50	3.55	4.41

*This value represents the average of readings on three random placings of apples of this sample, so that an average of red and green was obtained.
Note: Duplicates shown (lower figures) of some readings were made with ¾ inch gray strip across sample.

Likewise, the percentage of red color on the surface of the apple possibly may be defined in these terms which would be of particular value to the research worker.

Some problems on apple color which are opened for investigation by the colorimeter suggest themselves. The development of red and ground colors during the growth period of the fruit under various environmental conditions, as well as the changes during storage could be studied. The relation of quality of color to storage life is another problem. The defining of "characteristic" color of a variety which determines the grade of apples is of great practical importance, especially on some varieties which develop borderline color in some seasons. Varietal descriptions of color, especially from season to season and in different localities would be placed on a better basis for comparison and interpretation. Numerous other problems might be suggested.

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Effect of Thinning on Size and Color of Apples

By Lewis A. Fletcher, *U. S. Department of Agriculture, Washington, D. C.*

THE securing of satisfactory size and color on apples is an important problem in the Shenandoah-Cumberland Valley as in most other apple districts. During years of heavy crops good color development is frequently lacking. Although many of the orchards in this region receive good general cultural treatment, only a comparatively few orchards are thinned commercially, and much of this thinning is limited in degree.

The present paper gives 2 years' results on the effect of thinning on color development and size increase of fruit from trees of the York Imperial and Jonathan varieties. During 1931, distance between fruit was used as a basis for thinning, while in 1932 leaf area by spur count was used as a basis. Since many previous counts had shown that an average spur supported about 5 leaves, then one fruit was left on every tenth spur if 50 leaves per fruit were desired.

The growing season of 1931 had an annual rainfall slightly in excess of that of the 10-year average for the Shenandoah-Cumberland Valley, while the 1932 season had an annual rainfall below that of the 10-year average. The table below gives the monthly rainfall for the two seasons and the 10-year average monthly rainfall.

TABLE I—Rainfall 1931, 1932, and 10-Year Average. Hancock, Maryland

Year	May	June	July	August	September	Total
1931	4.91	3.72	3.60	3.98	2.00	18.21
1932	6.06	5.07	2.54	1.67	0.40	15.74
10-Year average	2.86	4.67	4.04	3.29	2.44	17.30

Results in 1931

The trees of the Jonathan and York Imperial varieties used during 1931 were interplanted. The trees grew in a rocky clay soil and were in a moderate state of vigor. Eight trees of each variety bearing a moderate crop were selected, and thinning on a "distance-between-fruits" basis was done on July 6. Irrigation by means of overhead sprinklers was practiced once a week, 12 hours at each irrigation, during the months of July and August. At harvest time for each variety the fruit was sized and graded for color. The data obtained for Jonathan are presented in Table II, and those for the York Imperial in Table III.

Table II shows that thinning gave a slight increase in color development, along with an increase in percentage of fruit in the larger sizes. The heaviest thinning resulted in a decreased yield

TABLE II—EFFECT OF THINNING ON COLOR, SIZE, AND YIELD OF JONATHAN APPLES, 1931. THINNED JULY 6, HARVESTED SEPTEMBER 28

Thinning Distance	Leaves per Apple	Yield Bushels	Per cent of Fruit Showing: 0–25 Per cent Color	25–50 Per cent Color	Above 50 Per cent Color	Percentage of Fruit: Under 2¼ ins. Diam.	2¼–2½ ins. Diam.	Above 2½ ins. Diam.
4–6 ins...	41.0	13.0	0.9	12.5	86.5	2.6	27.2	70.1
8–10 ins..	49.0	10.0	0.0	13.0	86.9	3.3	22.3	74.3
12–14 ins..	77.0	9.6	1.1	14.2	85.2	8.2	20.3	76.2
Check.....	38.0	13.7	.0	20.8	79.1	4.8	33.0	62.2

but gave the highest percentage of fruits of the larger size. It should be stated that the fruit was picked 2 weeks after commercial picking. At the time of commercial picking the color differences between the thinned trees and the unthinned trees were much more pronounced than when finally harvested.

TABLE III—EFFECT OF THINNING ON COLOR, SIZE, AND YIELD OF YORK IMPERIAL APPLES, 1931. THINNED JULY 6, HARVESTED OCTOBER 26

Thinning Distance	Leaves per Apple	Yield (Bus.)	Per cent of Fruit Showing: 0–25 Per cent Color	25–50 Per cent Color	Above 50 Per cent Color	Percentage of Fruit: Under 2¾ ins. Diam.	2¾–3 ins. Diam.	Above 3 ins. Diam.
4–6 ins...	21	22.4	0.6	26.0	73.0	32.2	45.1	21.0
8–10 ins..	37	20.7	0.25	16.6	83.1	28.7	37.7	33.5
12–14 ins..	53	7.2	0.0	5.9	93.9	4.3	6.5	89.2
Check.....	13	16.8	3.6	35.8	61.3	79.0	19.7	1.3

It is apparent from Table III that with the York Imperial variety there was a correlation between severity of thinning, color development, and size of fruit. As thinning distance increased, color development and size of fruit increased. Leaf area per fruit shows an increase with increase in thinning distances.

RESULTS IN 1932

Jonathan Variety.—The Jonathan trees used in 1932 were irrigated in 1930 and bore no crop in 1931. They grew in a heavy clay soil which supported an orchard grass sod. The trees were vigorous and had received nitrate for the past 5 years, though no nitrogen was applied in 1932. The trees were not comparable as to size but were comparable as to relative size of crop. Thinning to 50 leaves per apple and 100 leaves per apple on a "leaves-per-spur" basis was done on June 4 and June 18. The trees were irrigated by means of the furrow system once a week during July and August. At harvest time the crop from each tree was sized and graded for color. The data are shown in Table IV.

These data show that the Jonathan fruit increased in color development and size following thinning. Trees thinned to 100 leaves

per apple in early June produced no fruits having less than 25 per cent color, and over 70 per cent of the fruits were above 75 per cent color. The unthinned trees had 17 per cent of their fruits showing less than 25 per cent color and only 28 per cent showing above 75 per cent color. Trees thinned to 50 leaves per apple gave fruits

TABLE IV—EFFECT OF THINNING ON COLOR, SIZE, AND YIELD OF JONATHAN APPLES, 1932. FRUIT HARVESTED SEPTEMBER 28

Thinning Date and Distance	Effect on Color					
	Per cent Fruit Removed at Thinning Date	Yield (Bushels)	Percentage of Fruit Showing: 0–25 Per cent Color	25–50 Per cent Color	50–75 Per cent Color	Above 75 Per cent Color
Unthinned..........	—	20.1	17.2	24.1	30.0	28.5
June 4, 50 leaves per apple.............	51.1	11.4	6.8	15.8	33.7	43.5
June 4, 100 leaves per apple.............	58.2	6.9	0	5.0	18.0	76.8
June 18, 50 leaves per apple............	48.0	4.6	6.0	12.1	13.3	68.4
June 18, 100 leaves per apple.........	60.3	6.1	0.8	3.7	15.7	79.9

Thinning Date and Distance	Effect on Size and Yield				
	Percentage of Fruit: Under 2¼ ins. Diam.	2¼–2¾ ins. Diam.	Above 2¾ ins. Diam.	Aver. No. Apples per Bushel	Yield per 100 cm² Cross Section Area of Trunk (Bushels)
Unthinned...........	30.3	51.7	18.0	161	3.2
June 4, 50 leaves per apple..............	13.6	33.3	53.1	141	2.4
June 4, 100 leaves per apple.............	7.6	42.2	50.1	129	1.3
June 18, 50 leaves per apple.............	5.5	41.0	52.4	132	1.4
June 18, 100 leaves per apple.............	9.1	40.2	50.6	128	1.8

intermediate in color. Size of fruit was also increased by thinning as shown by the number of fruits required to fill a bushel basket. Yield has been decreased by thinning, although the yield in bushels per 100 cm^2 cross sectional area of the trunk does not show such a marked decrease as does total yield. From the above table it is apparent that 50 leaves per apple will result in good sized and well colored fruit on the Jonathan variety, when moisture supply is not a limiting factor.

Neither of the tables presented for the Jonathan variety show the effect of thinning on the quality of color developed. It may be stated that in every case the higher the leaf area the better the quality of color developed, quality being based on depth and

area of color. It was observed with the Jonathan variety that the greater the area of color developed the higher the quality of color.

York Imperial Variety.—The York Imperial trees used in 1932 were about 30 years old and grew in a heavy clay soil which supported an orchard grass sod. A block of 80 trees fairly uniform as to size and crop was selected in the fall of 1931. On April 21, 1932, 2 weeks prior to blooming, 40 of these trees received 10

TABLE V—EFFECT OF THINNING ON COLOR, SIZE, AND YIELD OF YORK IMPERIAL APPLES, 1932. FRUIT HARVESTED OCTOBER 16

Date Thinned and Treatment	Per cent Fruit Removed at Thinning Date	Yield (Bushel)	Percentage of Fruit Showing: 0–25 Per cent Color	25–50 Per cent Color	50–75 Per cent Color	Above 75 Per cent Color	Yield per 100cm² Cross sectional Area of Trunk (Bus.)	Fruits per Bushel
Unthinned, no nitrogen	—	10.2	10.9	29.0	29.6	30.1	1.7	164
Unthinned, nitrogen	—	17.5	28.2	32.2	22.7	16.9	2.6	178
June 20, 100 leaves per apple, no nitrogen	76.4	8.1	5.7	22.3	28.9	42.8	1.0	130
June 20, 100 leaves per apple, nitrogen	70.7	7.5	9.4	18.3	28.7	43.5	1.0	118
June 20, 50 leaves per apple, no nitrogen	67.7	13.7	11.8	18.6	25.2	43.4	1.7	140
June 20, 50 leaves per apple, nitrogen	60.4	14.9	15.3	31.0	24.0	30.2	2.0	124
July 5, 50 leaves per apple, no nitrogen	67.1	12.0	12.0	20.5	19.8	48.6	1.5	142
July 5, 50 leaves per apple, nitrogen	66.8	8.7	16.7	28.5	21.9	33.9	1.7	128
June 5, 50 leaves per apple, no nitrogen	59.0	12.3	10.9	28.8	35.3	24.9	1.0	142
June 5, 50 Leaves per apple, nitrogen	63.4	13.2	20.4	29.6	22.9	27.1	1.6	122

pounds of nitrate of soda. On different dates during the summer four trees which did not receive nitrate, and four trees which did receive nitrate, were thinned to 50 and 100 leaves per apple. At harvest time, October 16, records were taken on fruit color and size from each tree. The data shown in Table V is the average for four trees in each treatment.

From this table it is apparent that a spring application of nitrate of soda has resulted in a decrease in color formation in the unthinned trees and in those thinned to 50 leaves per apple. Fruit thinned to 100 leaves per apple had a color development on the nitrated equal to that on the non-nitrated trees.

The trees which did not receive nitrate in the spring showed a response to thinning in color development and size increase. The greatest color development and the largest-sized fruits were from the trees which had been thinned to 100 leaves per apple. The trees

which were thinned to 50 leaves per apple on June 5 did not show an increase in color development on fruits over that of the unthinned trees. There was, however, an increase in size of fruit from such a thinning. Trees thinned to 50 leaves per apple on June 20 and on July 5, showed a marked increase both in color and size of fruit over the unthinned checks.

The trees which received nitrate showed a color and a size response to thinning in every case. There was not such a marked response from the trees which were thinned to 50 leaves per apple on June 5. The greatest response was from the trees which were thinned to 100 leaves per apple on June 20.

Size increase of fruit as a result of thinning was more marked on the nitrated trees than on the non-nitrated trees. Thinning plus nitrate has resulted in increased size of fruit. It will be observed that in every case where thinning was practiced the number of fruit required per bushel was less for the nitrated trees than for the corresponding non-nitrated trees. Yield in bushels per 100 cm^2 cross-sectional area of trunk is higher for the nitrated trees than for the non-nitrated trees.

It should be emphasized that the tables shown here do not take into consideration quality of color on fruits. The consensus of opinion of several growers and research workers was that the fruits from the nitrated trees were of a brighter color than the fruit from the non-nitrated trees.

Relation of Foliage System and Fruit Thinning to Biennial Bearing in Apples

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A PREVIOUS paper (1) upon biennial bearing of apples showed that with vigorous trees very heavy fruit thinning in June, 1930, resulted in increased fruit bud formation. During that dry season non-irrigated trees showed more pronounced increases in fruit bud formation following thinning than did irrigated trees. These studies were continued in 1931, using York Imperial, the most important biennial bearing variety in the Shenandoah-Cumberland region.

Moderately vigorous trees near Hancock, Maryland, and less vigorous trees at Paw Paw, West Virginia, were used. At Hancock, the total number of growing points and fruits in 1931 on each large limb was counted. The number of leaves were calculated by multiplying the number of growing points by 5. When the trees were thinned, sufficient fruits were removed to leave the desired number of leaves per fruit for each scaffold branch. In the spring of 1932 the per cent of bloom on each limb was determined by counting all growing points and all blossoming points. The set was obtained by counting all fruits in June. Set, in proportion to bloom, was estimated by multiplying bloom times set and calling the product "crop."

At Paw Paw, West Virginia, fairly uniform thinning was accomplished by removing fruits until the correct number of leaves per fruit remained, as shown by inspection and occasional counts. Bloom records in 1932 were obtained by counting the blossoming points among several hundred growing points per tree.

Results with Vigorous Trees

Unthinned Trees.—Fifteen trees, with different amounts of crop in 1931, were left unthinned. Table I gives the fruit-leaf ratios in 1931 and the per cent bloom, the per cent set of blossoms, and the per cent of growing points carrying fruit in 1932. These data are based on the whole tree as a unit.

Tree 17, with 148 leaves per fruit in 1931, approximated a typical biennial bearing tree with the "off" year in 1931 and the "bearing" year in 1932. Trees C and 36, with 19 and 16 leaves per fruit respectively in 1931, were also typical of biennial bearing trees, but with their "bearing" year in 1931. The other unthinned trees were intermediate. Data in Table I indicate that, in general, trees with the greater number of leaves per fruit in 1931 bloomed more heavily in 1932.

TABLE I—RELATION BETWEEN LEAVES PER FRUIT IN 1931, AND BLOOM AND SET IN 1932, FOR UNTHINNED, VIGOROUS YORK IMPERIAL TREES

Tree Designation	Leaves per Fruit June—1931	Per cent Growing Points Blossoming 1932	Fruits per 100 Blossoming Points 1932	Per cent Growing Points Carrying Fruit 1932
17	148	82	41	34
7	70	60	45	27
8	70	61	42	26
1	70	18	51	9
22	50	24	42	10
16	50	17	113	19
2	39	28	74	21
5	33	11	11	1
18	29	12	50	6
21	27	12	32	4
K	27	26	58	15
15	26	23	55	12
14	24	8	57	5
C	19	2	35	1
36	16	0	0	0

Since individual limbs on these unthinned trees varied widely in leaf-fruit ratio, the data in Table I are presented in the first part of Table II, with large limbs as units. Regardless of the tree they were on, the limbs were grouped according to their leaf-fruit ratios in 1931, giving the weighted average of the bloom, set, and crop in 1932, for each leaf-fruit ratio. These data show that leaf-fruit ratios below 20 resulted in little or no bloom, while limbs with leaf-fruit ratios between 21 and 30 averaged 12 per cent bloom. Leaf-fruit ratios between 31 and 40 averaged 33 per cent bloom. Ratios above 40 leaves per fruit did not result in appreciably increased bloom, probably because many limbs with a light crop in 1931 were consistently light bearers, due to shading, lack of vigor, or other factors. These data for the unthinned trees supply a basis for evaluating the bloom on thinned trees, and determining whether or not the fruit thinning affected fruit bud formation for the following year.

Defloration.—On May 1, about 10 days before full bloom, 90 per cent of the bloom clusters were removed from two heavily blooming trees by clipping the flower cluster without disturbing the secondary spur growth. Contrary to expectations the remaining blossoms set lightly. The resulting leaf-fruit ratios were determined in June. This removal of 90 per cent of the bloom resulted in greatly increased fruit bud formation. This increased fruit bud formation was somewhat similar to that observed by Bailey (3) and Potter *et al* (6), following 100 per cent defloration. Auchter (2) found that defloration of only 150 spurs on a Stayman Winesap tree increased the fruit bud formation as compared with spurs which matured fruit.

Thinning on May 18.—On May 18, after petal fall, when many of the young fruits were showing distinct enlargement, young fruits

were removed from two trees to leave 100 leaves per fruit. Subsequent fruit drop undoubtedly increased the final leaf-fruit ratio, so that these thinned trees are not strictly comparable with the subsequently thinned trees. However, the data indicate that thinning

TABLE II—RELATION OF NUMBER OF LEAVES PER FRUIT TO BLOOM AND SET THE FOLLOWING SPRING, FOR UNTHINNED AND FOR THINNED TREES

Treatment	Leaves per Fruit 1931	No. Limbs	Per cent Bloom 1932 A	Per cent Set 1932 B	Crop 1932 A x B
Unthinned	0–10	1	0	0	0
	11–20	26	4	58	2
	21–30	29	12	50	6
	31–40	23	33	54	17
	41–50	17	21	64	13
	Above 50	55	34	52	18
90 per cent defloration May 1		6	40	37	15
Thinned to 100 leaves per fruit, May 18	0–10	13	49	93	45
	11–20	16	44	99	44
	21–30	2	29	76	22
	31–40	1	6	78	5
	41–50	1	6	163	10
	Above 50	2	22	63	14
Thinned to 100 leaves per fruit, June 4	0–10	4	50	43	21
	11–20	16	17	54	92
	21–30	15	26	39	10
	31–40	2	29	74	21
	41–50	5	24	55	13
	Over 50	5	30	75	22
Thinned to 100 leaves per fruit, June 18	0–10	3	0.6	117	.7
	11–20	23	18	87	15
	21–30	12	36	51	18
	31–40	6	23	58	13
	41–50	10	15	94	14
	Over 50	2	10	30	3.0
Thinned to 100 leaves per fruit, July 1	0–10	4	0.2	104	.2
	11–20	23	15	70	10
	21–30	10	9	64	6
	31–40	6	25	68	17
	41–50	2	20	88	17
	Over 50	11	12	41	45

on May 18 resulted in greatly increased bloom in 1932, and greatly increased set of bloom, as compared with the unthinned limbs.

Thinning on June 4.—On June 4, after the heavy drop of abscissing blossoms and small fruits, each large limb on four trees was thinned to leave 100 leaves per fruit. The bloom and set of bloom on all limbs with 0 to 30 leaves per fruit were increased by the thinning,

as compared with unthinned limbs carrying a similar original crop.

Thinning on June 18.—Each large limb on six trees was thinned on June 18, to leave 100 leaves per fruit. Limbs with 10 or less leaves per fruit before thinning did not show more bloom in 1932 than did comparable limbs on unthinned trees, but limbs with 11 to 20 and with 21 to 30 leaves per fruit did show increased bloom and set of bloom. As with the trees thinned on June 4, limbs with 31 or more leaves per fruit before thinning did not show more bloom in 1932 than the unthinned trees.

Thinning on July 1.—When each limb on six trees was thinned on July 1, to leave 100 leaves per fruit, only the limb with 11 to 20 leaves per fruit before thinning showed any increased bloom, as compared with the unthinned limbs. Since the thinned limbs with 21 to 30 leaves per fruit before thinning did not show increased bloom the following spring as compared with the check, the increased bloom of the thinned limbs with 11 to 20 leaves per fruit is probably not significant.

Results with Less Vigorous Trees

The less vigorous York Imperial trees at Paw Paw, West Virginia, were thinned on June 10, June 24 and July 8, respectively, leaving either 50, 100, or 200 leaves per fruit on each of two trees.

TABLE III—Effect of Thinning York Imperial Trees in 1931, Relatively Low in Vigor, Upon the Amount of Bloom in 1932

	Un-thinned	Thinned on June 10–11			Thinned on June 24–25			Thinned on July 8–9		
Leaves per Fruit after Thinning..........	14	50	100	200	50	100	200	50	100	200
Per cent Bloom 1932...	.5	2	9	6	1	.7	4	.3	6	3
	4.0	3	18	13	8	0	2	0	6	2

The data in Table III, based on the behavior of entire trees, show that with the exception of the heavy thinning on June 10 thinning of these trees did not result in consistently more bloom than occurred on two comparable unthinned trees. The bloom data for the trees receiving heavy thinning on June 10 suggests that even with trees relatively low in vigor, heavy, early thinning increased fruit bud formation.

Effect of Thinning upon Spur Growth.—When the samples of the 1931 growth of blossoming, non-setting spurs, typical for the tree, were obtained during 1931 for chemical analysis, the average green weight per spur was determined. The average green weight, based on five samples (between July 18 and Dec. 8) from each of duplicate trees, showed that 90 per cent defloration on May 1, thinning on May

18, and thinning on June 4 resulted in significantly greater weight than thinning on June 18 or on July 1, or no thinning. Spurs on trees thinned on June 18 and on July 1 averaged slightly heavier than on the unthinned trees. Increased spur growth was observed by Potter *et al* (6) following 100 per cent defloration of Oldenburg, but not following 50 per cent defloration. Auchter (2) observed increased secondary spur growth on 150 completely deflorated spurs, as compared with spurs maturing fruit.

Carbohydrate analyses of the entire 1931 growth of these spurs for reducing sugars, total sugars, starch, and total polysaccharides show that on July 13, August 7, September 12, October 8, and December 8, 1931, only the 90-per cent-defloration treatment resulted in more starch and total polysaccharides, expressed either on the green weight or dry weight basis, than occurred in the unthinned trees. Similar lack of correlation between fruit bud formation and spur composition was reported by Potter and Phillips (7). Reducing sugars and total sugars were approximately the same for all trees analyzed. Since the spurs on the trees receiving the 90 per cent defloration on May 1, the thinning on May 18, and the thinning on June 4 were larger than the spurs on the unthinned or later thinned trees, the absolute amounts of carbohydrates per spur were greater for deflorated or earlier thinned trees.

Analysis of the fruit held for 21 days at 60 degrees F following harvest, to allow maximum conversion of starch to sugars, showed the fruit from thinned trees to be about 20 per cent higher in total sugars.

Summary

On unthinned trees bearing a heavy crop the amount of fruit bud formation was somewhat dependent upon the leaf area per fruit. There was less fruit bud formation with lower leaf areas per apple on branches carrying less than 40 leaves per fruit. Thinning to increase the leaf area per fruit resulted in increased fruit bud formation where vigorous trees were thinned heavily on or before June 18, but not where they were thinned on July 1. With less vigorous trees, thinning on June 10 had less effect in increasing fruit bud formation than with the more vigorous trees. Thinning the less vigorous trees on June 24 and on July 8 had no apparent effect on fruit bud formation. In vigorous trees, heavy fruit thinning within 6 weeks of the blossoming date is apparently effective in increasing fruit bud formation for the following year.

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The Effect of Sulfur Fungicides Applied During Bloom on the Set of Apple Fruits

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ABSTRACT

EXPERIMENTS conducted at Ithaca, in the Champlain Valley, and in Western New York, in which sulfur dust and lime-sulfur spray, 1–40, were applied to apple blossoms at various times with relation to pollination, indicate (1) that lime-sulfur spray and sulfur dust were about equal in reducing the set, and (2) that greatest reduction was caused by application 24 hours before pollination and next greatest by application coincident with pollination. After intervals of 24 hours or more, reduction in set was noticeable but not serious. Under favorable pollination conditions, the data indicate that spray or dust can be applied late in the blooming period without serious reduction.

Cutting off the stigmas of flowers next the ovary at various intervals up to 24 hours after pollination, prevented setting of fruit. Cutting them off after 48 hours had little effect when daily maximum temperatures were about 80 degrees F. With daily maximum temperatures of about 65 degrees F, this treatment prevented set until after an interval of 60 hours.

Possibilities of Affecting Biennial Bearing in York Imperial Apples in the Cumberland-Shenandoah Valley

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VARIOUS methods have been proposed by different investigators to change the biennial bearing habit of certain apple varieties so that annual bearing would result. It is impossible in this short paper to review all of these methods or the complete literature on the subject. Two of the methods have been especially emphasized in the literature.

The first method, given largely by Roberts, (1, 2) consists, among other things, in obtaining a combination of good growth conditions (20 per cent of the terminals over 10 inches), variable spur growth, good diameter, moderate blossoming, particularly of the 2-year wood, a small percentage of lateral blossoming, and moderate cropping. Roberts found that these conditions were associated with annual bearing trees, and it seemed necessary to obtain such conditions if biennial varieties were to become annual bearers.

Method 2 as given by Hooker, who made many valuable contributions to our horticultural literature, suggested that annual bearing might result if nitrogenous fertilizers were applied in the spring of the off-year and were supplemented if necessary by similar applications in the fall of the same year, (4–6). He stated, "The off-year the tree suffers from an insufficiency of nitrogen." His work showed that spring applications of nitrogen reduced the starch content of non-bearing spurs in June of the same year, (3, 5), while fall applications tended to increase the starch content of such spurs the following July (4, 6) at about the time that fruit bud differentiation usually occurs in Missouri (4). His work indicated that spring applications in the off-year, by stimulating the growth of certain spurs and reducing their starch content, might inhibit fruit bud formation in the case of some of them during the off-year. Such spurs especially with an increased starch content in July of the crop-year might thus form fruit buds for the next year and by such means annual cropping might result, (4–6).

Hooker realized, however, that spring frosts had aided materially in affecting the beneficial results which he secured (6). He questioned the desirability of applying nitrogen in the spring of the crop-year in the case of biennial bearing varieties and stated, "Since spring applications of nitrogen increase the set and tend to decrease starch accumulation in June on trees in good growing condition, it would seem inadvisable to apply nitrogen to alternate bearing varieties in the spring of the bearing year," (4). With

these two methods in mind the Maryland experiments and results are now considered with special reference to the possibility of affecting biennial bearing of the York Imperial apple under Maryland conditions.

Plan of the Experiments

Investigations 1920–1924.—In 1920, six hundred 16-year-old York Imperial apple trees growing on a slope in one of the Western Maryland orchards were selected for these experiments. The trees were divided into acre plots consisting of two rows of 18 trees each, running up the slope. Various spring treatments of nitrogen and pruning and different soil cultural methods were given to the trees in the different plots in an effort to secure different growth conditions. In some plots the treatment consisted only of special pruning, in others special nitrogen applications without special pruning were made, while in still others both nitrogen applications and special pruning were given. Some plots received the treatments in the off-year, some in the crop-year and some every year. All plots were duplicated under both the sod mulch and the clean cultivation and cover crop conditions.

The trees in 1920 were in a moderate state of vegetative vigor and bore an average of 12 bushels per tree. Late spring frosts occurred in the years 1921 and 1922, killing a large percentage of the bloom so that very small crops were produced in those years. However, in spite of any of the treatments and the different growth conditions secured, a large crop was produced in 1923, followed by no bloom or fruit and an off-year in 1924. Detailed individual tree records of terminal and spur growth, trunk circumference, per cent of blossoming, yield, and other data were obtained on these plots for this period of four years, but it is apparent that with the complete off-year in 1924 following the large crop in 1923, that none of the trees had become annual in bearing habit up to that date.

Investigations 1924–1932.—With the complete off-year in 1924 an unusual opportunity was presented to start experiments to determine the effects of adding nitrogen in the fall of the off-year as compared to applying it in the spring; also to try a combination of spring and fall applications in the off-year, and to study the effect of such treatments upon biennial bearing as compared to the effects secured from similar applications made the next or on-year while a crop was being produced. Thus, various plots were laid out, including fall nitrating every year, fall nitrating used to supplement spring nitrating in the off-year only, fall nitrating plus spring nitrating every year, and spring nitrating every year. Some rows also received a special detailed pruning. Ammonium sulphate also was used in comparison with nitrate of soda and both materials were used in different plots varying in amounts from 5 pounds of nitrate of soda per tree to 20 pounds or its equivalent in ammonium sulphate.

Effect of Special Pruning, Spring Applications of Nitrogen Each Year, Spring and Fall Applications Each Year, Frost and No Special Treatments on Growth and Biennial Bearing

The special pruning which had been used in the years 1920–1924 was largely a type of pruning designed to stimulate spur growth and long terminal growth in an attempt to obtain over-vegetative spurs which would not form blossom buds in the off-year. In the winter of 1924–25 a more detailed type of pruning was used on two rows, namely, rows 38 and 39. Row 38 received heavy applications of nitrogen both in the spring and fall every year while row 39 received nitrogen in the spring only each year. The type of pruning was designed to remove the weakly growing type of wood, mainly small branches bearing older spurs. It was felt that otherwise this weak wood would be stimulated by any pruning and nitrogen applied and undoubtedly would form a large number of blossom buds in the off-year, thus resulting in excessive blossoming and a tendency to biennial bearing.

The large amounts of nitrogen used on such trees together with the cultivation, plus the detailed pruning, were considered sufficient to induce the development of strong vegetative growth of terminals as well as spurs and thus meet the growth conditions which have been considered by some to be associated with annual bearing. Abundant rainfall and good growing conditions in the season of 1924 together with the absence of a crop and this special pruning and large applications of nitrogen resulted in the development of good terminal and spur growth conditions including a large percentage of terminal growths over 10 inches in length. In 1924 the average terminal growth made by the trees in row 38 was 11 inches with 32 per cent of the terminals over 10 inches in length. The average terminal growth of row 39 was 10.3 inches with 35 per cent of the terminals over 10 inches in length. On the other hand, trees in row 48 (check) made an average terminal growth of 4.5 inches with practically no growths over 10 inches in length. Then, in 1925 with the continued use of this special detailed pruning and nitrogen, growth conditions similar to 1924 which normally are associated with annual bearing were again maintained.

In the spring of 1925, however, there was another frost but the effect on the block of trees was not to completely kill the blossoms on all trees in the row as occurred in 1921 and 1922, but rather to kill almost all the blossoms on the trees at the bottom of the slope, part of the blossoms on the trees half way up the slope, and only a few of the blossoms on the lower parts of some of the trees on the upper part of the slope. Therefore, the trees in the middle of the rows had about half of the blossoms killed, apparently uniformly over the trees. The effect of this frost on the future blossoming and cropping of the trees in the lower part of the rows, the middle part of the rows, and the upper part of the rows is shown in Table I.

TABLE I—THE EFFECTS OF SPECIAL PRUNING WITH SPRING APPLICATIONS OF NITROGEN EVERY YEAR, SPRING AND FALL APPLICATIONS EVERY YEAR, AND NO TREATMENT IN COMPARISON TO FROST AS A FACTOR IN INFLUENCING BIENNIAL BEARING OF YORK IMPERIAL APPLE TREES. (THE OCCURRENCE OF A FROST IN THE BLOOM AND YIELD DATA IS INDICATED BY BOLD FACE)

Year	Lower Trees in Row (Biennial Except in 1928–'29)						Middle Trees in Row (Annual in 1925–'26–'27)						Upper Trees in Row (Biennial)					
	Row 38		Row 39		Row 48		Row 38		Row 39		Row 48		Row 38		Row 39		Row 48	
	Bloom %	Yield Bus.	Bloom %	Yield Bus.	Bloom %	Yield Bus.	Bloom %	Yield Bus.	Bloom %	Yield Bus.	Bloom %	Yield Bus.	Bloom %	Yield Bus.	Bloom %	Yield Bus.	Bloom %	Yield Bus.
1924....	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1925....	68	0.7	61	0	53	0.8	73	12.5	72	15.3	60	11.6	59	15.3	77	20.8	73	18.1
1926....	73	12.7	69	15.6	45	16.1	35	15.3	18	13.7	15	11.0	6	6.8	4	4.7	2	3.5
1927....	4	0.8	6	0.8	3	0.9	70	17.9	95	22.8	58	7.4	96	28.1	95	30.8	83	23.5
1928....	100	9.5	100	14.0	64	10.9	13	2.8	8	1.0	31	3.8	0	0	0	0	0	0
1929....	47	14.1	55	13.3	14	6.4	75	18.1	83	17.2	85	17.3	91	20.5	92	28.4	92	23.8
1930....	15	1.1	56	2.7	60	4.6	1.5	0	2	0.5	5	1.6	0	0	0	0	0	0
1931....	95	17.2	91	24.2	70	15.1	88	23.3	85	23.8	85	17.8	72	26.2	92	27.6	90	18.5
1932....	0	0	4	0.5	16	4.4	0	0	0	0	0	0	0	0	0	0	0	0

EXPLANATION:

TREATMENTS: Row 38 received sodium nitrate, 10 lbs. in spring and 10 lbs. in fall, annually, plus special pruning.
Row 39 received (lower trees) sodium nitrate, 20 lbs. in spring, annually, plus special pruning; (middle and upper trees) sodium nitrate 10 lbs. in spring, annually plus special pruning.
Row 48 received no fertilizer and no special pruning (check).

Frost occurred in the years 1925, 1928, and 1930. Regardless of fertilizer and pruning treatments, biennial bearing existed except where partial injury to blossoms by frost in some years resulted in the production of annual crops in certain parts of the rows, as explained in the text.

Although all trees in the rows continued to receive the same treatments, the trees in the lower part of the rows became and continued biennial in habit in spite of their growth conditions through the years 1924, 1925, 1926, and 1927. Likewise, the trees in the upper part of the rows were biennial in habit during these years although the crop-years alternated with the trees in the lower part of the row. It will be noted, however, that a light crop was borne in 1926 on the upper trees in the treated and check rows. This light crop on these upper trees probably was due at least in part to the slight blossom injury of 1925 as noted above. The trees in the middle of the row which were partially injured by frost in 1925 became annual bearing in habit for 3 years and then became biennial again beginning with an off-year in 1928. However, the trees in row 48, a check row which had not received special pruning or nitrating and which as a result did not have the desirable growth conditions in any year, reacted in exactly the same way. The trees half way up the slope became annual bearers while those at either end of the row were biennial, the crops being produced in different years, as in the case of the specially treated trees.

In 1928 another frost occurred, but trees on only the lower part of the rows were partially injured, and as a result these biennial trees now became annual in bearing for 2 years during 1928 and 1929. In spite of moderate blossoming in 1930 they reverted again to biennial bearing due to another frost which reduced the crop greatly in 1930. The trees in the middle part of the rows had blossomed lightly in 1928, and there was no bloom on the trees in the upper parts of the rows. These trees in the upper parts of the rows were not affected by the frost factor and continued to produce crops in alternate years the same as the trees in the middle parts of the rows.

The behavior of these trees in rows 38, 39, and 48 thus were very similar as noted in Table I, regardless of the considerable differences in growth conditions which resulted from the different treatments of the trees. Other experimental rows with still different treatments in this same orchard behaved in a similar manner regardless of treatment or growth condition. The trees in row 48 with no fertilizer and no special pruning had practically no growth of 10 inches in length, and the average terminal growth and spur growth was considerably less than the growth of rows 38 and 39.

Blossoming of Two-Year Wood.—The trees in rows 38 and 39 blossomed moderately in 1925 with a relatively small percentage of 2-year wood blossoming, and a small percentage of terminal and lateral blossoming, hence it was felt that conditions were adequate for the repeated blossoming of 2-year wood in 1926. The blossoming of 2-year wood, however, was not responsible for the annual bearing of the trees in the middle part of the row since in 1926 the bloom was located largely on the older spurs of the tree. Heavy blossoming of 2-year wood occurred, however, on these annual

bearing trees in the middle part of the row in 1927. Thus, the 2-year wood on the annual trees was blossoming in a cycle every other year, and not every year as might be expected from the growth and blossoming conditions of 1925. Heavy blossoming on the 2-year wood, however, was evident in 1926 on the trees on the lower part of the row which had all the bloom killed by frost in 1925. Likewise the terminal and lateral blossoming was heavy even on the longer terminals. The lack of very much lateral blossoming on the annual bearing trees in the middle part of the rows in 1925 and 1926 did not result in the formation of blossoms on 2-year wood annually.

When the trees came into heavy blossoming, regardless of whether they had been annual or biennial in habit, lateral blossoming was heavy and was not related to length of terminal growth. In fact, the longer types of growth on heavy blossoming trees were more apt to have a heavy lateral blossoming. In other words, it appears that even with trees of different growth conditions and vigor, seasonal conditions which favor blossom bud formation may result in heavy blossom bud formation on laterals, terminals, 2-year wood and older spurs. In seasons which do not favor blossom bud formation, the very vegetative types of trees may not form blossom buds in excess numbers and this apparently was the case during the season of 1924 with exceptional rainfall and growing conditions. Thus, depending upon other factors, growth conditions of the trees may or may not be associated with a moderate blossoming of the tree.

Annual Bearing Non-vegetative Type of Tree.—Another type of tree which should be noted at this time is the non-vegetative type of tree which forms a small percentage of blossoms on its spurs annually, relatively few of which set fruits. This results in annual light crops on such trees. Very weak trees, of course, do not behave in this manner.

Effects of Fall Applications of Nitrogen Every Year, Spring Applications Every Year, and Spring and Fall Applications in the Off-year on Biennial Bearing—1924–1932

In Table II some data are presented on the effect of fall applications of nitrogen made in the off-year to supplement spring applications during this same year. It is seen that applications were made on row 17 in the spring and fall of 1924 when the trees were in an off-year and again in 1925 when the lower trees, as a result of frost, were again in an off-year. The lower trees in the rows responded with heavy blossoming and a heavy crop in 1926 followed by an off-year in 1927 in spite of the fertilizer treatments in the off-years preceding 1926. In 1927, another off-year, fertilizer applications again were made in the spring and fall. Heavy blossom-

TABLE II—COMPARISON OF FALL APPLICATIONS WITH SPRING APPLICATIONS OF NITROGEN EVERY YEAR AND WITH SPRING AND FALL APPLICATIONS IN THE OFF-YEAR IN COMPARISON TO FROST AS A FACTOR IN INFLUENCING BIENNIAL BEARING OF YORK IMPERIAL TREES. (THE OCCURRENCE OF A FROST IN THE BLOOM AND YIELD DATA IS INDICATED BY BOLD FACE)

Year	Row 17 (Sod)					Row 18 (Sod)					Row 41 (Cultivated)				
	Nitrate Application	Lower Trees		Middle Trees		Nitrate Application	Lower Trees		Middle Trees		Nitrate Application	Lower Trees		Middle Trees	
		Bloom %	Yield Bus.	Bloom %	Yield Bus.		Bloom %	Yield Bus.	Bloom %	Yield Bus.		Bloom %	Yield Bus.	Bloom %	Yield Bus.
1924	8 lbs., spring 10 lbs., fall	0	0	0	0	8 lbs., spring	0	0	0	0	8 lbs., spring	0	0	0	0
1925	10 lbs., spring 10 lbs., fall	76	0	88	8.3	10 lbs., spring	86	0	72	11.0	20 lbs., fall	79	0	73	22.6
1926	None	96	15.8	37	11.9	20 lbs., spring	91	16.8	57	11.7	20 lbs., fall	79	24.9	13	15.5
1927	10 lbs., spring 10 lbs., fall	2	1.1	45	10.0	20 lbs., spring	9	1.6	58	12.3	20 lbs., fall	0	0	78	24.0
1928	None	96	13.4	70	8.8	20 lbs., spring	98	16.9	60	6.2	20 lbs., fall	99	17.8	15	2.8
1929	5 lbs., spring 5 lbs., fall	59	9.6	93	15.7	10 lbs., spring	56	9.5	90	18.9	20 lbs., fall	33	10.5	80	19.6
1930	None	43	4.8	1	0.7	10 lbs., spring	48	3.4	2	0	20 lbs., fall	64	6.0	3	1.5
1931	5 lbs., spring 5 lbs., fall	54	15.8	57	17.2	10 lbs., spring	69	16.6	83	21.8	20 lbs., fall	76	19.5	68	21.5
1932	None	43	10.1	17	1.7	10 lbs., spring	26	7.1	2	0.3	20 lbs., fall	0.6	0.3	0	0

EXPLANATION: Frost occurred in the years 1925, 1928, and 1930. Regardless of fertilizer treatments the frosts of 1925 and 1928 resulted in the production of annual crops from 1925 to 1929, inclusive, on the middle trees of the rows, while the frosts of 1928 and 1930 resulted in the production of crops during the years 1928 to 1932, inclusive, on the lower trees of the rows. The 1925 frost destroyed all the blossoms on the lower trees but only injured part of the blossoms on the middle trees. The 1928 and 1930 frosts extended up the hill far enough to partially injure the blossoms on both lower and middle trees, as explained in the text.

ing followed in 1928 but the crop was reduced by a certain amount of injury to blossoms by late spring frosts. This injury was sufficient to cause repeated blossoming to a moderate degree, as was the case in rows 38 and 39 (Table I) and a moderate crop resulted in 1929. The annual condition persisted in 1930 as far as blossoming was concerned but the crop was reduced by late spring frosts to a small crop. As a result, there was repeated blossoming in 1931 with a moderate crop and the annual condition persisted in 1932 with a fair crop.

It will be noted that practically identical results were obtained on the lower trees of the adjacent row 18 where nitrogen was applied every year in the spring. Row 41 (except for 1932) which received fall nitrating every year and row 48 (check row Table I, lower trees) responded in the same way. Thus, it is apparent that the spring and fall applications in the off-years (and any other treatments of 1924 and 1925) and the following 3 years were ineffective in producing annual bearing during the 3 years, 1926, 1927, and 1928, but the frosts of 1928 and 1930 resulted in annual cropping of these same trees during the 5 years 1928 to 1932, inclusive, regardless of the treatments which they had received during these years. The middle trees in these two rows which had received the same treatments and which had only a partial reduction of the crop by frost in 1925 and again in 1928 produced five successive crops of moderate size during the 5 years 1925 to 1929, inclusive. This result was similar to the annual cropping of the lower trees during the period of years 1928 to 1932 as just described. Too much weight should not be given to the 8-year average actual or total yields per tree under the different treatments because of the frost factor and variability in the size of trees.

Conclusions from Investigations and Suggested Possibilities of Affecting Biennial Bearing

Various cultural, fertilizer, and detailed pruning treatments of York Imperial trees in Maryland have failed to materially influence the biennial bearing habit of this variety even though the growth conditions of the trees approached the vegetativeness which has been associated with annual cropping. Probably, the moisture factor, especially during the period of the initiation of flower buds is of great importance in this section. Moderately low moisture conditions (but not low enough and extended over long enough periods to seriously decrease the normal functioning of the various parts of the tree) which usually prevail during this time tend to favor blossom bud formation with the result that practically all types of growth in many years may form blossom buds, which results in a biennial condition. Irrigation of such trees would aid in maintaining satisfactory soil moisture conditions and thus directly or indirectly through changed growth conditions might reduce ex-

cess blossom bud formation in the off-year and at the same time help to provide better conditions for blossom bud formation in the on-year.

One factor influencing biennial bearing in the Shenandoah-Cumberland Valley region which has been evaluated fairly well in this work is the frost factor. In those years when all blossoms are not destroyed, its effect in thinning of the blossoms entirely from some spurs and thus reducing the total crop results in conditions favorable for successive blossoming and annual crops. The removal of the blossoms reduces the number of fruits per tree so that there is an increased leaf area per fruit. This lessening of the total number of fruits to be developed and matured undoubtedly allows for some accumulation of carbohydrates in many cases which apparently results in increased blossom formation on the non-bearing spurs. The effectiveness of this early blossom thinning becomes apparent and indicates that possibly even thinning of fruits, after setting, especially if the thinning is done heavily enough to greatly increase the leaf area per fruit left, may become an important means of obtaining annual bearing as suggested by Aldrich (7). The good growth conditions which seem desirable for fruit production possibly will assist materially in the effect of this thinning operation by producing a large leaf area per tree. Certainly heavy early thinning together with a combination of those practices of pruning, soil management, spraying, and fertilization best suited to stimulate excellent growth conditions and healthy foliage should help in bringing about annual crops. If in addition to the above practices water could be added to the soil when needed it would seem that conditions should be nearer satisfactory for the production of crops year after year.

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The Effect of Pruning of Excised Shoots on the Transpiration Rate of Some Deciduous Fruit Species

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ASIDE from the experiments of Cullinan (1) on the effect of dormant pruning on the transpiration rate of the apple, and the work of Darrow and Sherwood (2) with its effect on the strawberry, the author is unaware of any published information on the effect of pruning on the transpiration rate of deciduous fruits. During the summer of 1931 opportunity was given to study the effect of pruning on the transpiration rate of five species of fruits growing on the Horticultural Farm of the Illinois Agricultural Experiment Station, Urbana, Illinois. It is the purpose of this paper to present the results of these experiments.

The species and varieties used were red raspberry (Latham), apple (Tolman Sweet), cherry (Early Richmond), pear (Kieffer), and peach (Gage Elberta).

Shoots of the current season of medium vigor were selected in each case, except the peach, in which more vigorous current season shoots with laterals were used. Pruning the apple, cherry, and pear consisted in the removal of single leaves; with the peach, laterals with several leaves were cut off; in the case of the raspberry, pruning consisted of the removal of the compound leaves. In all the series, approximately one-half of the foliage was pruned off, every other leaf or lateral being removed. The pruning cuts were covered with melted paraffin.

The potometer method of measuring transpiration was used. The shoots were cut under water as they were placed in the potometers and were allowed to become adjusted for 2 to 4 hours before pruning. Readings started immediately after pruning. The experiments were conducted in a well-ventilated laboratory in which the light, temperature, and air circulation were quite uniform for all the shoots in any series, but no attempt was made to control these variables. The leaf area was determined with a planimeter.

DISCUSSION OF RESULTS

Data for the 12 series included in the experiments are summarized in Table I. With the exception of one series with the apple, the removal of approximately half the foliage caused an increase in the rate of transpiration per unit area of the remaining leaves. This was true whether the pruning consisted of the removal of simple leaves or compound leaves or the cutting off of laterals, as was done with the peach. Increases in rate ranged from 22 to 93 per cent.

TABLE I—EFFECT OF PRUNING ON THE RATE OF TRANSPIRATION OF EXCISED SHOOTS

Series	Date of Collection	Variety	Length of Test Period (Hours)	Average Rate of Transpiration (cc per sq. in. per hour)		Ratio of Pruned to Unpruned (Per cent)
				Pruned	Unpruned	
1	June 27	Early Richmond	22	.0147	.0089	165
7	July 24	Early Richmond	65	.0185	.0143	129
8	July 27	Early Richmond	67½	.0126	.0076	166
2	June 29	Latham	45	.0180	.0101	178
3	July 1	Latham	42½	.0172	.0131	131
4	July 7	Latham	38	.0175	.0092	190
5	July 9	Kieffer	39½	.0249	.0179	139
6	July 21	Kieffer	42½	.0351	.0231	152
9	July 29	Elberta	42	.0081	.0042	193
10	Sept. 29	Elberta	42	.0117	.0070	167
11	Oct. 8	Tolman Sweet	20	.0364	.0297	122
12	Oct. 12	Tolman Sweet	63½	.0317	.0319	99

EXPLANATION: Approximately half of the foliage was removed on each pruned shoot. Sixteen shoots were used in each series, half of which were pruned, with the exception of series 11 and 12, in which 8 and 10 shoots, respectively, were used.

A possible explanation for the failure of pruning to increase the transpiration rate in series 12 is the fact that throughout most of this experimental period the relative humidity was high, reaching a maximum of 87. This suggests that under environmental conditions unfavorable to rapid transpiration, the removal of foliage may not affect the rate, and that the increase in rate will be greater under conditions of low humidity and high temperature when the plant is subjected to considerable stress because of a high rate of water loss. The higher increase in rate of the peach in series 9 during the latter part of July as compared to the same species a month later is also in favor of this explanation.

The increase in transpiration rate per unit area of foliage due to pruning may have a bearing in the study of the rise of water in woody stems. It indicates that the rise of water is not due entirely to the "pull" of transpiration, or the rate per unit area would remain about the same on pruned and unpruned shoots. The rise in rate also suggests that the leaves on a tree are in competition for water or the increased rate may be due to the tension in the vessels. If it were due entirely to the latter, the increase should be only temporary, but measurements made daily for a period of nearly 3 days indicated that the increased rate was not temporary. It seems reasonable to assume that in a shoot there is normally an adjustment between the size and number of the vessels and the leaf surface. When leaves are removed by pruning, this balance is at least temporarily disturbed. The absorbing power of the roots and the conducting power of the tree remain much the same while the transpiring leaf surface is reduced. The individual leaf on a pruned shoot is able to transpire at a higher rate, and still remain turgid,

than a leaf on an unpruned shoot as long as there is an adequate supply of water in the soil.

In these experiments approximately half the foliage was removed on the pruned shoots. Since the rate of transpiration per unit area was increased by pruning, perhaps an average of about 50 per cent, the removal of foliage actually resulted in the conservation of water. In this direction these experiments may have some practical significance. Recent experiments by a number of investigators have indicated that under a given set of environmental conditions, increase in leaf area per fruit beyond a certain point is of no apparent value in fruit development. In periods of severe drought when high temperatures and low humidity prevail, and trees that have been over-stimulated by nitrogen fertilization are suffering because of inadequate moisture, the supply in the soil may be conserved by the removal of superfluous foliage by shoot pruning. The frequent failure of nitrogen fertilizers to increase the size of fruit may be due, under conditions of stress at least, to the loss of water through foliage in excess of that required for normal fruit development.

Summer pruning should be practiced with the understanding that it may delay wood maturity and dwarf the tree to some extent, but pruning done in late summer when droughts are most severe would perhaps ordinarily cause little or no stimulation, and the dwarfing effect upon the top and roots should be at a minimum because of the relatively short period the tree would be deprived of the excess foliage.

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Growth of Five- and Six-Year-Old Transplanted Apple Trees

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THIS paper presents data relative to the growth of transplanted 5-year-old Grimes (not "double-worked") and 6-year-old Jonathan trees (5 and 6 years after receiving the trees from the nursery). In the late fall of 1919 and of 1920, four trees of each variety were selected for uniformity of size and vigor and transplanted in a cylinder of earth about 4 feet in diameter and 2 feet deep. The method of moving these trees was described by Pickett (2). Before transplanting, heavy heading back and thinning out was given each tree; thereafter light pruning has been practiced. For a check of the growth rate, these trees are compared with: For Grimes, 2-year Grimes planted in the late fall of 1919 and also 2-year Grimes planted in the late fall of 1914; and for Jonathan, 2-year Jonathan trees planted in the late fall of 1913. The 1913 planting of Jonathan and 1914 planting of Grimes are in the orchard from which the transplanted trees were moved. All the lots are located within a radius of 200 feet in a brown silt loam.

The trunk circumferences of the four lots of transplanted trees and Grimes planted in 1919 have been recorded at intervals since 1921. Those for 1921 reported by Carver (1) appeared too small to represent circumference readings; therefore borings were made to check on his readings. It then became apparent that his 1921 readings were for trunk diameters and not trunk circumferences, and they are so considered here. Unfortunately two bits were broken in taking samples and another could not be secured, therefore readings for the years when no circumference measurements were taken could not be filled in for all trees. Measurements for the non-transplanted Jonathan trees set in 1913 and of Grimes set in 1914 were taken only in the fall of 1932. Since borings could not be secured for all the trees, trunk circumferences have been calculated as radii for those trees in which such measurements could not be secured. That such a calculation is in close agreement is shown by the readings where both circumferences and borings were made. For Grimes planted in 1919 the average circumference was 27.7 inches in 1932 and calculated from borings 27.6 inches, and for Jonathan transplanted in 1919 the average circumference was 34.6 inches in 1932, and calculated from borings, 34.2 inches.

Data on the radial growth for the various lots are given in Table I, and the average growth for each lot is shown graphically in Fig. 1, each year's radial increase being plotted. Radial increases shown in Fig. 1 for which all the readings are not given in Table I were determined after plotting curves built up on the known readings given in the table.

TABLE I—SHOWING THE INCREASE IN GROWTH FOLLOWING PLANTING OF 2-YEAR-OLD GRIMES AND 5- AND 6-YEAR-OLD TRANSPLANTED TREES. MEASUREMENTS ARE GIVEN ON THE RADIUS OF THE TREE IN MILLIMETERS. MEASUREMENTS ON TREES MARKED WITH AN ASTERISK WERE CALCULATED FROM CIRCUMFERENCE READINGS AND NOT FROM BORINGS

Variety, Age of Tree, and Planting Date	Radius of the Trees Taken in the Late Fall (Mm)																				Circum. (Ins.)
	1913	1914	1915	1916	1917	1918	1919	1920	1921	1922	1923	1924	1925	1926	1927	1928	1929	1930	1931	1932	
2-year medium							6.0	8.0	16.0	21.0	27.0	37.0	45.0	47.0	52.0	61.0	69.0	80.0	92.0	102.0	
Grimes							6.0	9.0	14.0	24.5	32.5	38.5	47.5	57.5	66.0	76.5	84.0	92.5	102.0	109.5	
planted							9.0	13.5	18.5	24.5	31.1	37.7	45.0	54.3	62.6	71.6	78.9	87.5	96.1	104.1	
fall 1919							8.5	12.5	19.5	28.5	33.5	39.5	49.0	58.5	67.5	76.0	83.5	92.5	101.0	110.0	
							7.5	18.5	30.5	37.5	45.5	56.5	67.5	79.0	90.0	100.5	109.0	117.0	126.0	137.0	
							8.0	11.0	16.0	23.0	29.5	36.5	47.0	55.5	63.5	72.0	79.5	88.5	99.0	108.5	
Average....							7.5	12.1	19.1	26.5	33.2	40.8	50.2	58.6	66.9	76.3	83.9	93.0	102.7	111.8	27.6
Average of Grimes trees planted in the fall of 1914 but not transplanted........																				113.5	28.2
5-year-old Grimes							22.0	23.0	26.0	29.0	31.0	37.0	45.0	54.0	61.0	68.0	73.0	79.0	86.0	92.0	
transplanted									25.4		40.6	47.3				87.0	94.0	105.0		121.3	
fall 1919							25.0	29.0	31.0	43.0	49.0	55.0	64.0	72.0	81.0	92.0	99.0	109.0	120.0	129.0	
	*								24.5		34.0	39.0				70.7	84.0	104.0		111.0	
Average....							23.5	26.0	28.7	36.0	38.6	44.6	54.5	63.0	71.0	79.4	87.5	99.2	103.0	113.1	28.0
5-year-old	*								22.3		26.5	32.8				63.6	77.7	88.8		108.2	
Grimes	*								25.4		34.5	41.0				77.3	82.8	91.0		105.1	
transplanted	*								28.5		40.7	48.1				87.0	94.0	103.0		123.3	
fall 1920	*								28.5		35.8	43.0				72.8	77.7	84.0		100.0	
Average....									26.2		34.4	41.2				75.1	83.0	91.7		109.1	27.0
Average of Jonathan trees planted in the fall of 1913 but not transplanted......																				143.1	35.4
6-year-old	8.3	11.9	16.5	21.1	24.7	29.3	34.9	38.9	47.3	56.1	64.3	72.9	83.3	91.5	98.3	105.9	112.5	119.5	128.9	138.7	
Jonathan	7.0	10.0	14.0	18.0	24.0	29.0	35.0	38.6	44.6	53.6	62.9	71.5	81.1	87.7	93.7	101.3	106.6	115.2	126.2	133.2	
transplanted	11.0	15.0	19.0	21.5	25.5	30.5	35.0	37.5	46.0	52.5	62.0	73.0	80.0	92.0	101.0	111.0	117.0	127.0	136.0	146.0	
fall 1919	6.0	11.0	13.0	17.0	23.5	30.0	35.3	39.6	42.6	49.9	59.9	69.5	76.1	85.7	93.7	102.3	113.9	119.5	128.1	134.7	
Average....	8.1	11.9	15.6	19.4	24.4	29.7	35.1	38.6	45.1	53.0	62.4	71.7	80.1	89.2	96.7	105.1	112.5	120.3	129.8	138.1	34.2
6-year-old	*								34.9		48.0	63.1				91.0	95.8	108.8		125.3	
Jonathan	*								34.9		50.5	58.3				97.8	102.3	112.1		131.2	
transplanted	*								34.9		51.5	59.0				105.1	107.2	115.1		134.2	
fall 1920	*								28.5		44.8	52.6				95.0	101.1	108.1		125.8	
Average....									33.3		48.7	58.2				97.2	101.6	111.2		129.1	32.0

Considering first the growth rate of the Grimes planted in 1919, it is apparent that they have made a very uniform growth since 1920, laying down 6 to 10 mm of new wood each year. This lot of trees in the fall of 1932 measured 111.8 mm in radius of 27.6 inches in circumference, and are average sized trees of this variety as grown on the Urbana farm when the trees are pruned but moderately the first 2 years followed by light to very light pruning thereafter.

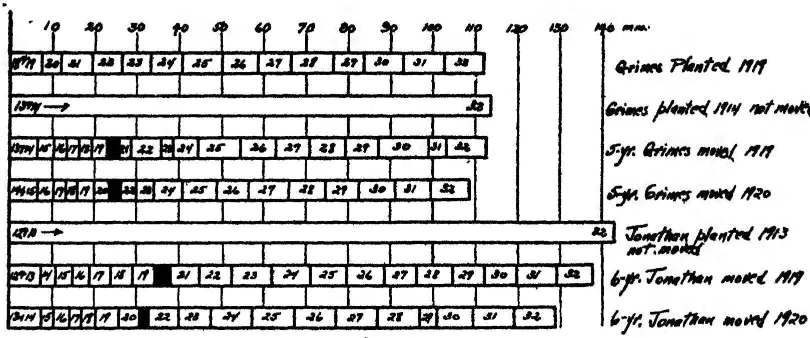

FIG. 1. Showing the average yearly increase in radius for the seven lots of trees

With the 1919 transplanted Grimes it was impossible to determine by borings the yearly growth laid down before 1919 due to the inner heartwood entirely breaking up in extraction. However, from borings secured on two trees the difference between the 1932 size and that laid down from 1920 to 1932 was 22 mm and 25.0 mm, respectively, or an average of 23.5 mm. The trees when moved were selected for uniformity in size, therefore the above average can be considered as closely approximating the tree sizes of those moved in 1919 and not much different from those planted in 1914, but not moved. The average size for the above lot of transplanted Grimes was 17.3 mm less in radius than the 1919 planting of Grimes after they had grown for 5 years. This average size (23.5 mm) is slightly smaller than the 1919 planting after they had been out but 3 years. The cause for the small size at the 5-year period cannot be fixed exactly at this late date, but, since the four lots of transplanted trees showed the same tendency it would appear that the same factor or factors were responsible for all. Probably the rather heavy pruning recommended and practices used at that time in securing the framework were responsible in a large part for this slow growth and small size. After transplanting, both the 1919 and 1920 lots of Grimes made very little more yearly growth during the next 4-year period, than they had before being reset. When 10 years of age, those trees moved in 1919 measured 40.8 mm; the 1920 transplanting 49.5 mm; while those set in 1919, had a radial size of 83.9 mm. After the 10-year period both transplanted lots started laying down new wood at the same rate as the 1919 planting, and in

1932 there is little difference in size between the two lots, and the 1919 planting.

With Grimes set in 1914 (trees of the same planting from which the 1919 transplanted trees were secured) but not moved, the average size in 1932 was 113.5 mm in radius, while those transplanted in 1919 measured 113.1 mm. If the non-transplanted trees were of the same size in 1919 as those which were moved, transplanting has not resulted in a smaller tree, as would be indicated when they are compared with those planted in 1919.

The two lots of transplanted Jonathan showed the same slow growth, as did the Grimes, before they were moved. Even though the 1919 transplanting were 6 years old when moved, they were but very little larger than the 1919 planting of Grimes when they were 4 years old, and the 1920 lot were a little smaller than the Grimes. After being reset, the 1919 lot laid down about as much new wood as before, while the 1920 lot grew very little the year after moving; thereafter both lots grew at a fairly uniform rate, and in the fall of 1932 the 1920 lot was the equivalent of 1 year's growth behind the 1919 lot, or the difference in age of the trees. Jonathan planted in 1913 and not moved, averaged 143.1 mm in 1932, this being but 5 mm larger than the 1919 lot which was moved. If the trees planted in 1913 and not moved were of the same size in 1919 as those which were moved, the transplanting has not retarded growth to any marked degree.

The growth laid down after transplanting, and the little size difference between the non-transplanted and transplanted trees, indicates that the root pruning and heavy heading back given the trees when they were moved was not enough to cause dwarfing. Undoubtedly the small size of the trees when moved and the large amount of earth moved with the trees contributed greatly to their recovery following transplanting. From a commercial standpoint replacing dead trees with 4 to 6-year old trees would be a practical method of making such replacements, trees being grown for this express purpose outside the orchard.

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Ultropaque Microscope Equipment as an Aid in Stomatal Studies[1]

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A NUMBER of different methods have been described for the study of the stomatal behavior of leaves. The three principal microscopic methods which have been widely used by many investigators with apparently a high degree of satisfaction are the direct observation of the stomata made visible by passing a powerful beam of light through the uninjured leaf (1) the removal of small areas of the epidermis and subsequent immediate fixing of this tissue with absolute alcohol (1) and the removal of small areas of the epidermal layer and immediate observation of this tissue mounted dry (2). Recently Ultropaque microscope equipment, which is essentially a modified form of an illuminator utilizing incident light, has become available. The image is formed by reflected rather than by transmitted light.

It seemed that this equipment might provide a very desirable means of studying stomatal behavior. The specimen could be observed in an almost normal state without being subjected to the possible seriously disturbing influences of exposure to a powerful beam of light, or changes in epidermal tissue brought about by the killing and fixing in absolute alcohol or by exposure to dry air. By means of the Ultropaque the living leaf could be conveniently observed on the plant, if desired, with practically no injury to any part of the leaf.

Such equipment was used by the writer throughout the past season in a study of the stomatal behavior of peach leaves. The standard equipment was modified to permit it to be readily used in the commercial orchards.

Energy for the small 8-volt lamp which serves as a light source was provided by means of a 6-volt storage battery connected in series with one or two dry cells. A small variable rheostat permitted the regulation of the current so that it provided the desired light intensity but did not over-load the bulb. Portabilty of the microscope was permitted by connecting the illuminator to the batteries by means of a hundred-foot, rubber-covered extension cord.

Use of incident light for illuminating an object makes the use of a cover glass over the specimen undesirable, as reflections from the surfaces of the cover glass produce a haze.

However, it is necessary under orchard conditions, that the leaf be held firmly in place. If the microscope is equipped with a focusing object stage the specimen can be secured to the stage.

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The microscope used in this study did not have a focusing object stage; therefore a mechanical stage attachment was employed. To hold the leaf firmly to the slide without injury the following device was used, namely, along one edge of the slide near each end were attached two narrow flaps made of a few thicknesses of gummed cloth tape stuck together. These flaps were hinged to the slide by means of small pieces of the tape and were held down with small wire clips. Such an arrangement held the specimen firmly and practically flat. It could be manipulated rapidly.

In practice the whole leaf was removed from the stem, and placed on the slide. The flaps were folded over the specimen and each was clipped down. The space between the flaps permitted a portion of the leaf of about one-half square inch in area to be observed.

With the use of the Ultropaque the guard cells appeared as brightly outlined contours. If the stoma was closed a bright line was seen between the elliptical contour of the guard cells. If the stoma was open a dark area was seen between the guard cells. This dark area varied in shape from a narrow line when the opening was small to nearly circular when the opening was large.

This method of stomatal observation compared very favorably with the dry-mount method previously mentioned, when used with peach leaves under orchard conditions. Stomata on the peach leaf are particularly readily seen, as the leaf surface is relatively smooth and flat. No detailed study has been made, to date, with this method using plants under carefully controlled conditions although such a study is planned. However, leaves of many different plants have been observed by the writer by means of the Ultropague. In every case this equipment has seemingly been satisfactory for the purpose desired.

It is believed that the advantages of this method of stomatal observation are that it affords an opportunity to observe the leaf at any time without serious injury, on the living plant if desired; it permits the ready and accurate observation of a great number of stomata at one time and without delay; and it makes possible the observation of practically any portion of the leaf surface that is desired.

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Some Observations on Stomatal Movements in Hicoria Pecan

By B. G. Sitton, *U. S. Department of Agriculture, Shreveport, La.*

IN connection with studies of the influence of irrigation and cultural practices upon pecan production, observation of the behavior of stomata seemed desirable. Review of literature indicated that the cobalt chloride paper, the hygroscope, and the porometer methods are generally considered unsatisfactory.

Stripping off the epidermis and immediately plunging the strip into absolute alcohol, a method originated by Lloyd (2), has been used extensively with other plants. Magness and Furr (5), working with apple foliage, also stripped the epidermis but mounted it dry and observed the stomata immediately. Neither of the latter two methods could be used with the pecan because when stripping was attempted the piece carried much tissue other than epidermal, so that only a narrow margin around the edge of the piece was thin enough to be observed with a high-power microscope. The small number of stomata thus visible cannot be considered a reliable index of the average condition, as Lloyd has shown with alfalfa that all of the stomata on a leaf are not open to the same degree at any given time, and observations on leaves of the pecan have confirmed these findings. To be reliable, each observation should include 50 or more stomata and they should be observed as rapidly as possible.

Observing the unaltered leaf by transmitted light, another method described by Lloyd (3) is unsatisfactoty. The stomata of the pecan are so small (fully open pores averaging about 4μ x 11μ) that high magnification is necessary, which brings the objective lens so close to the leaf surface that condensation of moisture occurs on the lens.

During the fall of 1930, vertical illuminators were tried and one type gave excellent results. This one was an illuminator with two types of reflectors which could be used interchangeably, *viz.*, a total reflecting prism and a reflecting glass plate. The latter was found to be more satisfactory for routine observations, but the former proved useful for photographing the stomata. This illuminator also had an adjustable condenser and an iris diaphragm by which the light could be adjusted. For use with the illuminator, a special short mounted objective was necessary, and one having a focal length of 4 mm., a magnification of 45 and a numerical aperture of 0.85, was found satisfactory.

A mechanical stage was found convenient for rapidly observing a large number of stomata. The fogging of the objective previously mentioned was not encountered with the use of the vertical illuminator.

A portion of the leaf may be placed on a slide, with the lower side up and secured in place with T clips, using no cover. The epidermal and guard cells appear light green while the aperture between the guard cells of a wide open stoma appears dark. It is sometimes hard to distinguish between the degree of opening of a stoma nearly closed and one that is entirely closed, but all other stages of openings can be readily distinguished. The length of the pores changes very little as the stomata close, the closure being accomplished almost entirely by a decrease in width,-which results in a change in shape. The stage of closure can be instantly classified by the shape of the pore so that there is no need to estimate the width of the opening. It was found that 100 or more stomata could be observed in about a minute and that the stomata on a portion of a leaf on the microscope did not change materially in 2 minutes.

A careful check, using leaves of alfalfa, banana, and corn, indicated that the condition of the stomata could be determined as rapidly and as accurately with the vertical illuminator as with the two methods of Lloyd.

It is not the purpose of this paper to give a detailed account of the movement of stomata as influenced by differing conditions of orchard management, but some generalizations will probably be of interest. Apparently, from the observations made, the stomata of the pecan do not open until direct sunlight, or very bright diffused light, strikes the leaf, and no considerable proportion of the stomata on a tree were ever found completely open at the same time. Apparently, after the stomata open, they remain open as long as exposed to sunlight, if soil moisture is abundant and transpiration not excessive. However, with low soil moisture or high evaporating power of the air, the stomata may close earlier and reopen within a short time. The entire process may take place within the period of an hour and this closing and opening may be repeated. Closure shortly after noon and a reopening within 2 hours has been reported for other plants (1, 2, 4, 5, 6). In some instances, this closure is associated with an increase in humidity or a decrease in temperature, or both. The reopening of the pecan stomata occurred early in the afternoon when the evaporation rate and temperature apparently were still high.

Stomata of leaves from trees growing in a soil whose moisture content was near the wilting point closed as early as 10 a. m. and remained closed the rest of the day.

Observations have not been made throughout the night but were occasionally begun before dawn and continued until dark. Stomata of the pecan were never found open before sunrise nor after sunset.

Open stomata have not been found on leaves growing on the lower inside of the tree where they were almost completely shaded, although it is possible that the stomata do open slightly for short

periods. Seldom were stomata found open in the forenoon on leaves from the west side of the tree. Leaves growing on the north side of the tree were frequently observed with stomata partly open in the forenoon, closed around midday and open again in the afternoon, as the leaves were in sunlight, then shade, then sunlight again. Stomata on leaves on the south and southeast sides of the tree usually remained open for a greater part of the day than those on leaves on the rest of the tree which was observed. The variations in stomatal behavior in the different parts of the tree may be associated with the apparent tendency of large trees to produce nuts principally in the tops and on the south and east sides of the tree, and with the dying of the inner branches of the tree common to the Stuart variety. These observations were made on mature leaves of the Stuart variety in an orchard where the trees are beginning to crowd at 68 feet spacing.

Investigations at present have not revealed the significance of the observed behavior of the stomata, and further investigations are necessary before the entire behavior will be known.

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A Simple Device for Use in Leaf Area Studies

By Richard V. Lott and H. W. Le Mert, *Mississippi State College, State College, Mississippi.*

In conducting studies which involve leaf areas the investigator has at his disposal several methods of measurement, including (1) tracing the leaf outline on coordinate paper and counting the spaces; (2) tracing the leaf outline on paper of uniform thickness, cutting out and weighing, and comparing this weight with that of a known area of the same paper; (3) printing on sensitized paper and measuring with a planimeter; (4) the direct use of the planimeter; and (5) the methods used by Darrow (1).

Since leaf area studies of horticultural crops require relatively large numbers of leaves and since the time of the investigator is nearly always somewhat limited when the leaf samples are taken, he is confronted with the problem of securing the accuracy of the planimeter with the minimum use of time. Direct use of the planimeter is usually unsatisfactory, particularly with crinkly edged leaves such as those of the peach. The leaf edges may be held down by a glass plate, but the planimeter tends to skid unless ground glass is used. Furthermore, such measurements are very time-consuming.

With the above points in mind, for several years the senior author has used ordinary blue print paper. The paper has been cut into convenient sized pieces, the leaves placed on the paper under a glass plate and the whole exposed to sunlight until the light has reduced the iron of the ferric ammonium citrate in the paper to the ferrous condition, giving the characteristic blue precipitate of ferrous ferricyanide in the exposed areas of the paper, while in the areas covered by the leaves the characteristic yellowish color of the paper remains. The paper can be washed and an ordinary blue print thus secured or if stored in darkness washing is not necessary. At the convenience of the investigator the leaf areas can be determined rapidly with the planimeter. This method has given good results, but it has been somewhat cumbersome and not well adapted to field conditions.

The authors have developed a device which is easily operated, consumes much less time in operation, and is adapted to laboratory or field use. It is a box-like structure measuring 16 x 9 x 3 inches. In one end, on suitable supports, is a roll of blue print paper 8 inches wide on a spool similar to those on which kodak film is wound. In the other end is a similar spool equipped with an outside turning device. The spool compartments each require 3 inches of the length of the box, leaving an area 10 inches long and 9 wide in the center. This area has a false bottom placed 3/8 inch from the top, on which is a pad of felt or sponge rubber 1/4 inch thick. Covering this pad is a piece of glass 8 by 10 inches hinged at the back

and having a hinged cover. The end of the roll of blue print paper is passed through a slit at the top of the inside wall of the roll compartment, over the resilient pad and through a slit in the inside wall of the spool compartment to the spool to which it is attached. To operate the device, the glass and its cover are raised, as many leaves as possible placed on the paper, the glass fastened down with a clamp, and the whole exposed to sunlight until the blue precipitate of ferrous ferricyanide appears in the exposed places. The glass plate is then lifted and the spool turned until a section of unexposed paper is brought in place under the glass. The process is repeated as many times as necessary. When the roll is completely exposed, it can be removed and the leaf areas determined with the planimeter or it can be stored until a more convenient time. Rolls have been stored successfully for several months without washing, but for permanent records washing should be done. Any desired data can be written on each exposure. The time consumed in exposure is usually about sufficient for the selection of the leaves for the next exposure. Obviously, this device can be used only for leaves which have been removed from the tree.

The 8 x 10 inch exposure area seems to be the most convenient for the leaves of most fruit trees, accommodating 6 to 8 large peach leaves, which is as many as the operator can properly handle. For leaves such as those of the fig or the grape and of many vegetables a larger model could be constructed. A model with two glass plates would double the exposure area and would still be fairly easily handled.

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Winter Injury to the Crotch and Trunk of the Apple Tree

By FRANK HORSFALL, JR., *University of Missouri, Columbia, Mo.*

A NUMBER of investigators have believed that nutrition is one of the bases of hardiness. The tissues that are best supplied with something which comes from the leaves, (1) probably carbohydrates, are thought to be most resistant to winter injury. In line with this idea it was thought that, as an experimental procedure, ringing or severe root pruning after August 1, would, by reducing the volume of possible underground storage space, cause a greater deposit of food reserves in the trunk and crotches of the tree.

The first part of this study was undertaken in an attempt to determine whether or not the following factors have any bearing upon the sugar, starch or hemicellulose content of the trunk or crotches of the Grimes or Stayman apple trees: (1) Ringing the tree at the crown before dormancy; (2) trenching around the tree 20 inches deep at a radius of 7 to 9 feet from the crown.

Samples taken January 12 and February 29, 1932, from checks and from trees receiving the ringing and trenching treatments between July 31 and August 15, 1931, were analyzed for sugar, starch, and hemicelluloses. The results showed that only minor differences in the content of these substances existed between different trees or between parts of the same tree. Such variations as were discovered were not significant in regard to the treatments given.

The effect of root pruning on hardiness through restricting water supply was not studied. No killing point determinations were made, consequently the actual hardiness of the various tissues which were analyzed is not known.

The trees used in the experiment grew on Memphis Silt Loam. This fact, together with a late autumn and weather well suited to maximum maturity, may in a measure account for the lack of significant positive data.

The second part of this investigation was a field study made in June, 1932, of a northwest Missouri apple orchard. This river bottom tract contained about 3000 fourteen-year-old trees which showed a number of winter injured crotches which must have become affected during the severe winter of 1929–30, although the date is uncertain. Most of the commercial varieties of this section were represented in the orchard.

The results of the winter injury survey indicate that there is a close correlation between winter injury and the distance or obstruction separating the foliage from the lower parts of the tree. The leaves seem to contribute something that increases hardiness. A study of the component parts of gross tree anatomy indicates how certain tissues may become isolated from the leaf areas upon which they depend. Injuries of any sort and structures which partly cut off or

distantly remove an area from the leaves upon which it depends apparently cause the region below to be more subject to winter-killing. A number of conditions under which this form of susceptibility occurred were observed.

Possibly as a result of adaptation to maximum exposure of leaves to the sunlight, the secondary branches from scaffold limbs seem to arise more frequently from the sides and outer or lower part of the scaffold limbs rather than from the upper part (1). As conduction along the limb takes place in more or less straight lines, the place where most of the leaf elaborated substances must move is determined by the point where this material enters the scaffold limb. We see that scaffold limb crotches are effectively cut off from most of the supply from the limb forming the crotch because the movement is in the sides and lower part of the scaffold limb and not through the crotch. In the specimens studied it was observed that the upper part of the scaffold limb enlarges more slowly than the rest of the limb. This retarded development may be related to movement of substances from the leaves.

Spiral girdles on the trunks of apple trees have been shown to cause the regenerated conductive tissues to change the direction of longitudinal axis from normally parallel to the limb to parallel with the spiral (2). Present evidence indicates that such spiral girdles have the same effect on scaffold branches. If such can be proven for scaffold limbs the course of conduction from the leaves can be so changed that the maximum will be through the crotch to bring about increased hardiness. The peculiar subsequent development associated with spiral trunk girdles if also true of limbs might introduce other undesirable features.

Any crotch which is supplied with an impoverished stream from the upper part of the limb must receive the greater portion of its leaf-produced material from limbs attached higher on the trunk. Conductivity along the route from these upper limbs may be hindered by the structure or injury of the parts traversed.

Deficient translocation of leaf-prepared substances in the upper part of the scaffold limb must cause a lean supply to move into and through the crotch to the areas below lying along the lines of such reduced food conduction. Perhaps the somewhat twisted crotch tissues retard the movement or because of an apparently faster growth rate deplete further the food stream. A narrow killed strip about 1 inch wide was sometimes found along the trunk of the tree following the line of movement of the meager food supply which seems to pass through the crotch. Winter killing in the strip dependent on crotch conduction was observed on the trunk below both living and winter injured crotches but more often accompanied the death of the crotch. No case of a winter injured crotch lying at the lower end of such a killed strip was observed but doubtless the occurrence of this situation is highly probable.

Any crotch which is directly below another crotch, following the grain of the wood, is more liable to winter injury than a similar

crotch in other positions. The most favored place for a crotch low in the tree is directly below a higher limb, where the low crotch receives the rich unobstructed food supply moving through the phloem on the under side of such a higher limb.

Two crotches occurring laterally close enough together so that the two susceptible trunk regions depending on higher crotch conduction are side by side, create an extensive area subject to low temperature killing. In setting the tree, situations of this nature may chance to be placed at any point of the compass; consequently trunk injuries which are due to this cause might occur on any side of the tree. Such a vulnerable spot on the southwest side of a tree trunk, because of two independent factors, poor conduction and susceptibility to winter sun scald, is very subject to winter injury.

As a preventive of winter sun scald, the recommendation has been to plant the young tree with a lower limb in the southwest exposure. When the low limb is placed on the southwest side the more susceptible portion of the trunk connected through the crotch obviously is in another more favorable position. The more resistant part of the trunk under the limb is placed where sun scald would likely occur.

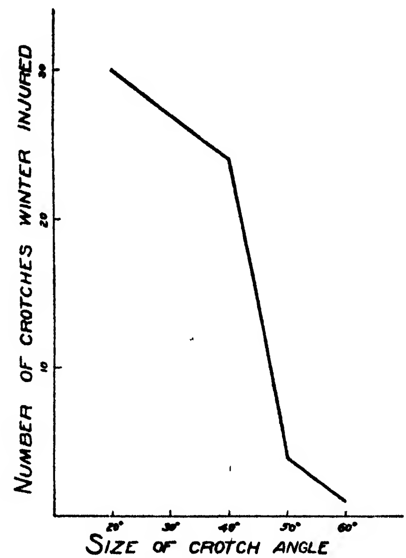

FIG. 1. The relation between size of crotch angle and susceptibility to winter injury.

Crotches formed between the sides of two limbs were not observed to be winter injured in a single instance regardless of how narrow they were. This fact is readily explained if we assume that because of their relation to the side of the limb these crotches are in a more direct line of conduction from leaves. Crotches formed by the sides of two limbs are usually physiologically closer to the folige than similar scaffold limb crotches which are in connection through the upper part of the limb.

The lower a crotch is located in a tree, other things being equal, the greater is the chance of winter injury. The explanation seems to be that low crotches are so remote from the foliage.

Trunks which divide at one point to form two or more large nearly equal scaffold limbs with a common crotch between them made up a very susceptible area. A crotch of this nature constitutes an isolated region where translocation must be very sluggish.

The removal of larger limbs frequently resulted in the death of rather extensive areas of the trunk below the limb scars. The trunk tissues dependent on the leaves of a limb are left subject to winter killing following the loss of the limb.

Fig. 1 indicates very forcibly that acuteness of the angle is closely correlated with injury to the crotch. As it appears that wide crotches are resistant to injury, it becomes very important to know how to induce a young apple tree to form limbs making a wide angle with the trunk. Talbert (3) found that cutting young apple trees back to short stumps at planting time, if set early enough or if cut back 1 year later, caused the scaffold limbs which formed to arise from the trunks at wide angles. These cut-back trees overtake the uncut-back trees after a few years.

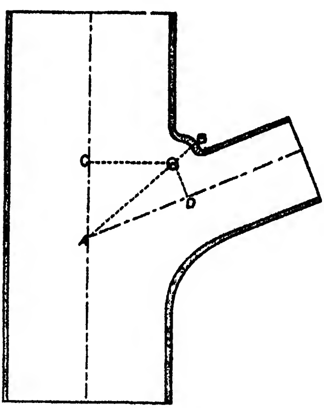

FIG. 2. Diagram of an apple tree crotch.

A median longitudinal diagram of a typical apple tree crotch with the limb and trunk practically the same age is depicted in Fig. 2. The drawing shows that during the life of the limb the trunk cambium has built up the tissue the length of C O. The cambium of the limb has developed the length of D O. As any except the narrowest crotches maintain growth rate sufficient to fill up the space, the crotch cambium must produce the tissue at least the length of A O. Now, since A. O is the common hypotenuse of the two right triangles A O C and A O D, it is longer than any leg of these triangles. In most crotches the total growth exceeds A O to some distance O B. The foregoing, together with the increased distance between annual rings along A O B, demonstrates the increased growth of the crotch when compared to the growth of the limb or trunk.

As the angle formed by the trunk and limb becomes smaller the ratio of A O to C O or D O becomes relatively greater until failure to make a satisfactory union occurs because of bark inclusions. A study of a number of Grimes apple tree crotches gives evidence that the distance between successive annual rings is greater in the more narrow crotches than in the wider ones. The crotch angles that approach 90 degrees are little, if any, more vegetative than adjacent tissue. These observations support the conclusion that susceptibility to crotch injury is greater in the narrow crotches. Apparently resistance of the wider crotches to winter injury is a result of slower growth rate.

The considerations regarding the evil effects of distance from

foliage and of one crotch on another must surely direct attention to the probability that wider angle crotches are less dependent on proximity to foliage than are the more narrow ones.

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Satsuma Orange Maturity and Quality

By H. P. Traub, *U. S. Department of Agriculture, Washington, D. C.*

Abstract

This paper will appear in the Journal of Plant Physiology.

The Relation of Tree Vigor to the Rate of Healing of Pruning Wounds in the Apple[1]

By W. G. Brierley, *University of Minnesota, St. Paul, Minn.*

As the healing of wounds is a growth process, it appears obvious that properly made wounds should heal more rapidly on vigorous trees than on those lacking vigor. In nearly all publications dealing with wound healing, general observation has been the basis for this conclusion. Observations of this nature carried on at the Minnesota Station gave results in agreement with similar studies elsewhere. Some evidence appearing in these studies, however, seemed to indicate that the rate of healing was not constant. More detailed studies were undertaken in 1928 to determine whether a correlation really exists between tree vigor and wound healing, and whether such correlation varies as healing progresses.

In a 12-year-old orchard located at University Farm in which Wealthy and Duchess were the principal varieties, the trees ranged in vigor from rather weak to fairly vigorous. To further increase the range of vigor, some of the more vigorous trees of each variety were fertilized each spring with 5 pounds of sulphate of ammonia per tree. At the beginning of the study in 1928 an average of five amputation wounds were made on 32 Duchess and 36 Wealthy trees. As an attempt was made to avoid severe pruning, fewer wounds were made on some obviously weak trees and the number slightly increased on some of the more vigorous ones. The number of wounds was slightly increased also when it appeared desirable to make use of smaller wounds. During the progress of the study a few wounds were discarded because of mechanical injuries, and one Wealthy tree died. At the close of the study, after the season of 1930, there were 32 Duchess trees with a total of 163 wounds and 35 Wealthy trees with 183 wounds.

As soon as the wounds were made and the areas recorded, a disinfectant containing mercuric bichloride, mercuric cyanide, and glycerine was applied in an attempt to lessen the danger of loss from wound parasites. On each tree the wounds were distributed as much as possible and large wounds avoided. Most of the wounds made were between 1 and 2 inches in diameter. A few year-old wounds were included in cases where it appeared likely that the making the usual number of new wounds might check the vigor of the tree; these were not numerous enough, however, to affect the general results materially. To facilitate recording of the wound areas, a small brad was driven into the center of each wound and another a few inches beyond the wound to establish a fixed center and axis. The wound patterns for each year were definitely

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centered and oriented by these fixed points. Zinc tags bearing a serial number were attached close to each wound. Thus each wound was identified in the orchard and on the record sheets by the row and tree number and the serial number of the wound.

Wound areas were obtained in the first season by tracing the cambium line on onion skin paper placed over the wound. The center point and axis also were recorded. Since, after overwalling started, this method could not be used, the wound margins were recorded on thin glass plates by means of a glass-marking pencil and transferred to the onion skin paper on which the original wound area was recorded.

The data relating to shoot growth were obtained by recording the total length of 20 new shoots selected at random for each tree and season. Trunk measurements were obtained at a fixed point by driving a small nail part way into the trunk at a height of 1 foot. Wound areas were obtained by planimeter measurements. In calculating the relative areas of the wounds each year the original wound was used as a base. In computing the several correlations the total wound area per tree reduced by the healing process was compared with the shoot growth and trunk increment of the respective trees and seasons.

TABLE I—CORRELATION OF RATE OF WOUND HEALING WITH SHOOT GROWTH—PRUNING WOUNDS MADE IN APRIL, 1928

Season	Wealthy	Duchess
1928	$.178 \pm .112$	$-.218 \pm .114$
1929	$.304 \pm .105$	$.183 \pm .115$
1930	$.590 \pm .075$	$.478 \pm .092$

The coefficients of correlation between the rate of wound healing and shoot growth for the two varieties over the three seasons are presented in Table I. Correlation between the rate of wound healing and trunk increment is similarly shown in Table II. In all cases the values for 1928, the first season after pruning, are so small that it is apparent that little correlation existed at that time

TABLE II—CORRELATIONS OF RATE OF WOUND HEALING WITH TRUNK INCREMENT—PRUNING WOUNDS MADE IN APRIL, 1928

Season	Wealthy	Duchess
1928	$.237 \pm .109$	$.248 \pm .112$
1929	$.616 \pm .072$	$.435 \pm .097$
1930	$.776 \pm .046$	$.508 \pm .088$

between tree vigor and the rate of wound healing. The negative value found in the case of the Duchess variety in Table I presumably indicates only that there was no correlation in that case. The values for 1929 indicate that the correlation between tree vigor and wound healing was increasing in significance but was still doubtful in some instances. The values for the season of 1930

show that a significant correlation existed at that time between tree vigor and wound healing.

There appears to be two explanations for the low correlation values found for the first year. Some of the wounds, particularly in the Duchess variety, dried back at the margins during the first season so that they were actually larger in the fall than in the spring. This behavior may help to explain the negative value for Duchess in Table I. The second explanation obviously may be found in the time required for the organization of the healing process. That the development of wound callus proceeds somewhat slowly in the case of amputation wounds has been clearly shown by Bradford and Sitton, (1). The correlations herein presented are in agreement with the histological evidence presented by these workers. These data also suggest that varieties may behave somewhat differently with regard to the relationship between tree vigor and wound healing. The results with both varieties indicate, however, that there is a definite correlation between tree vigor and the rate of wound healing, but that this is not in evidence in the season in which the wounds are made.

The writer gratefully acknowledges the assistance of R. E. Marshall, of the Michigan Experiment Station, in recording the orchard data for the season of 1928, and the painstaking work of Catharine Becker in calculating the correlation data.

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Vitamin C Distribution in Baldwin and McIntosh Apples

By C. R. Fellers, P: D. Isham, and G. G. Smith, *Massachusetts State College, Amherst, Mass.*

THE limited published data (3) on the vitamin C content of American apples show protective levels on guinea pigs from 10 to over 40 grams. Bracewell and co-workers (2) working with English varieties found Bramley's Seedling to give full protection from scurvy at a feeding level of 3 to 4 grams. Other varieties were much less active. These investigators (1) likewise found much greater vitamin activity in the flesh close to the epidermis than in the flesh near the core. The epidermis itself was not assayed.

Givens, McCluggage and Van Horne (4) obtained protection from scurvy with daily doses of 10 grams of raw apple juice. Heat preserved apple products were deficient in vitamin C. Robison (5) obtained protection from scurvy in guinea pigs at a 4-gram level by the use of concentrated apple juice. This amount was equivalent to about 24 grams of pressed juice.

Fellers, Cleveland, and Clague (3) recently discovered that the Baldwin apple is a rich source of vitamin C, that storage causes a gradual loss, that spraying the trees has no effect on the vitamin content, and that the freshly expressed juice also retains the vitamin. On the other hand, bottled or stored cider or canned, strained apple sauce have very little vitamin C. Additional data are now presented.

The method of Sherman, La Mer, and Campbell (4) for vitamin C determination was used. Young, 300-gram guinea pigs were fed a ration adequate in all respects except for vitamin C. The animals were forced to derive all of their vitamin C from this fruit. If the amount of fruit fed contained insufficient vitamin C, loss of weight accompanied by symptoms of scurvy occurred in from 15 to 30 days. At death or after the completion of the 90-day test period, the animals were autopsied and the scurvy lesions in the bones, teeth, joints, intestines, and muscles recorded on a score card. A normal animal has a score of 0 while the maximum score for extremely severe scurvy is 24.

Where whole apple was fed, radial sectors were cut. The guinea pigs were fed varying quantities of apple including skin. In general, at least three animals were used at each feeding level. The animals readily ate the apple, apple skins, and apple sauce, but it was necessary to force-feed the juice and cider by pipet in order to be certain that each animal received his full portion. Animals were kept in individual cages.

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[1]Contribution No. 162, Massachusetts Agricultural Experiment Station.

Comparison of Baldwin Apple Flesh and Epidermis

Apples held in storage from October to February 12 were used. The vitamin C content was about 20 per cent less than in freshly picked fruit. However, 5 grams daily afforded full protection from scurvy and gave normal weight gains. The apples were machine peeled and all adhering flesh carefully removed by hand from the epidermis. Next, the flesh was removed to a depth of approximately ¼ inch from the peeled surface. This sample constituted the "flesh near the skin" portion. Finally, the third portion constituting the "flesh near core" sample was cut from the pulpy area near the seed cells but did not include any seed cells or seeds. The data are represented in Fig. 1.

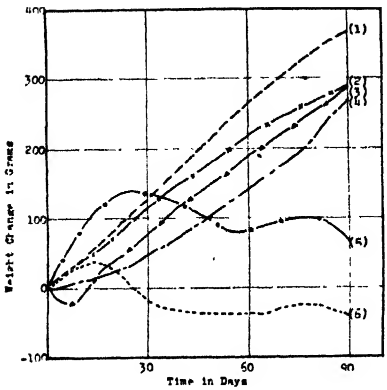
The epidermis is much richer in vitamin C than any other portion of the Baldwin apple tested, 1 gram daily giving excellent growth and full protection. It is probable that even 0.5 gram or still less would likewise be protective. Next in antiscorbutic activity comes the flesh near the epidermis. Three grams daily afforded full protection and gave maximum growth. One gram hardly sufficed to prevent scurvy, though small weight gains occurred. It is probable that 2 grams of the flesh near the epidermis would give full protection. On the other hand, 4 grams of the flesh near the core failed to maintain growth or protect, though 8 grams did so. On this basis the epidermis is about four times as rich as the flesh immediately beneath it, and six to ten times as rich as the flesh near the core.

Vitamin C in McIntosh Apples

The McIntosh apple has apparently not been studied in regard to vitamin C. The following experiments were conducted in the fall of 1932 while the fruit was fresh and firm. The authors wished to determine whether the distribution of the vitamin C in the McIntosh variety followed that found in Baldwin. However, only whole fruit (radial sectors, including epidermis) were compared, because of the surprisingly low antiscorbutic activity of the McIntosh The data are given in Fig. 2.

It is apparent that the McIntosh is approximately from $\frac{1}{6}$ to $\frac{1}{10}$ as rich in vitamin C as the Baldwin. Even 25 grams fed daily gives insufficient scurvy protection; that is, this variety is a very poor source of vitamin C. However, inasmuch as 2 grams of the epidermis gave a slight degree of protection, it is apparent that the epidermis is very much richer in vitamin C than the flesh.

In many vitamin studies, the variety factor has been either disregarded or assumed to be of minor importance. Manifestly this cannot be done in the case of apples. There is evidence that the vitamin-rich varieties, Baldwin and Bramley's Seedling possess the same chromosome count, *e.g.*, 51, while several of the vitamin-poor varieties, such as McIntosh and Worcester Pearmain, show counts of 34. This may furnish an explanation for variety variation



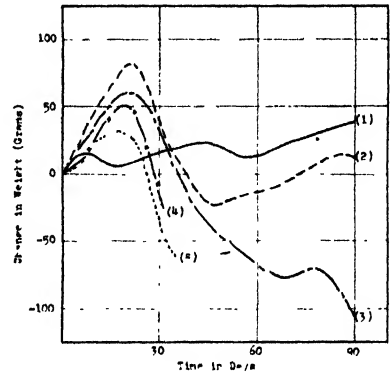


Fig. 1. Vitamin C in the Flesh and Skin of Baldwin Apples.

Explanation: Animals fed (1) 1 g. apple skin, scurvy score 0; (2) 3 g. apple flesh near skin, scurvy score 0; (3) 8 g. apple flesh near core, scurvy score 0; (4) 2 g. apple skin, scurvy score 0; (5) 1 g. apple flesh near skin, scurvy score 8; (6) 4 g. apple flesh near core, scurvy score 5

Fig. 2. Vitamin C Distribution in McIntosh Apples.

Explanation: Animals fed (1) 25 g. apple; (2) 2 g. apple skin, scurvy score 14; (3) 12 g. apple, scurvy score 14; (4) 0.5 g. apple skin, scurvy score 13; (5) 5 g. apple, scurvy score 16.

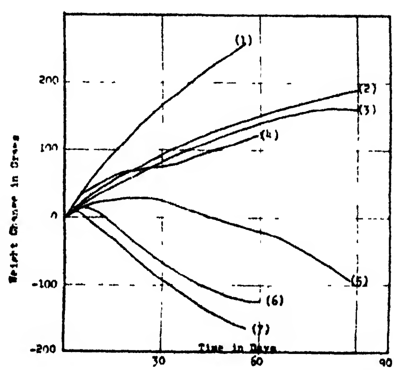


Fig. 3. Vitamin C in Baldwin Apple Juice, Fresh and Pasteurized Cider, and Apple Sauce.

Explanation: (1) 7.5 grams pressed cider, 1 to 7 days old, scurvy score 0; (2) 20 grams freshly made unstrained apple sauce, scurvy score 1.5; (3) 6 grams centrifuge extracted fresh apple juice, scurvy score 1.5; (4) 5 grams pressed cider, 1 to 7 days old, scurvy score 5; (5) 10 grams canned unstrained apple sauce, scurvy score 9; (6) 10 grams canned strained apple sauce, scurvy score 14; (7) 8 grams bottled pasteurized cider, scurvy score 14. Experiments 1, 2, and 4 were conducted Nov.–Jan. 1933; 3, May–July 1932; 5, 6, and 7, Feb.–Apr. 1932.

in vitamin C content. Several additional varieties are now being assayed for vitamin C with the idea of gathering further data on this question.[3]

Vitamin C in Apple Sauce and in Fresh and Preserved Apple Sauce

Large quantities of apples are consumed as apple sauce and apple juice or cider. Preliminary data (3) on these products manufactured from Baldwin apples in 1931 showed that freshly made apple juice (not pressed) retained nearly all of the vitamin C, while ciders preserved by heat pasteurization or sodium benzoate were very deficient. Similarly, canned, strained Baldwin apple sauce retained very little vitamin C.

A few additional assays of freshly prepared juice and apple sauce of the 1932 crop of Baldwin apples yielded data presented in Fig. 3. These curves are largely self-explanatory. It should be pointed out that though the vitamin C potency of the storage Baldwins used for the canned apple sauce and preserved cider was 5 to 6 grams daily per guinea pig, the fresh 1931 and 1932 crops protected fully from scurvy at the 4-gram level. The fresh centrifuge-extracted juice is only slightly inferior to the fruit itself. Pressed Baldwin cider stored at 38 degrees F for 1 to 7 days gave full protection from scurvy at the 7.5-gram level. Though weight gains were made at the 5-gram level, there was insufficient vitamin C to entirely prevent scurvy, the average score at autopsy after 55 days being five. That is, commercial sweet cider only a few days old, retains somewhat over 50 per cent of the vitamin C of the apples from which it is made.

No measurable vitamin C was found in canned strained apple sauce fed at the 10-gram level; canned unscreened sauce, though somewhat more active, could not be considered a good source of the antiscorbutic vitamin. Freshly prepared unstrained apple sauce, when fed at the 20-gram level, corresponding to 16 grams of fresh apples, gave good growth gains and nearly full protection from scurvy. On this basis, freshly made unstrained apple sauce retains approximately 20 to 30 per cent of the fruit's original vitamin C content.

Conclusions

The Baldwin apple and its freshly expressed juice are good sources of vitamin C. These foods gave complete protection from scurvy at the 4- and 7.5-gram levels, respectively. Benzoated or pasteurized ciders as well as canned apple sauce were poor sources of vitamin C. Freshly made apple sauce retains 20 to 30 per cent

[3]Since presenting this paper our attention has been called to a recent paper by Crane and Zilva, Jour. Pomology and Hort. Sci. 9:228–231, in which J. B. S. Haldane is credited with suggesting the possibility of correlating vitamin C with chromosome counts in apples. Belle de Boskoop and Blenheim varieties, both with chromosome counts of 51, were rich in vitamin C. However, Lane's Prince Albert, a 34 count variety, was fully as high as Blenheim. Other 32 count varieties were poor reservoirs of vitamin C.

of the original vitamin C content of the fresh apple. The McIntosh apple is a very poor source of vitamin C, 25 grams daily failing to protect guinea pigs from scurvy. In the Baldwin apple, the vitamin C is concentrated in the epidermis and in the fleshy cortex. The epidermis is about 4 times as active as the flesh near it and 6 to 10 times as active as the flesh in the pulpy area near the core. The epidermis of the McIntosh apple is likewise notably richer in vitamin C than the flesh itself.

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Field Trials with Lime-Sulfur and Koppers Flotation Sulfur in Apple Scab Control

By A. B. Burrell, and R. G. Parker, *Cornell University, Ithaca, N. Y.*

THIS is the first progress report of field studies on fungicides for apple scab control in the Champlain Valley of New York. The chief purpose of the tests herein discussed was to compare a promising new sulfur fungicide with lime-sulfur on the basis of effectiveness in apple scab control and injury to foliage and fruit. There was also interest in comparing a paste form of this new material with a dry wettable form. The Koppers flotation sulfur used was said by the manufacturers to be blended from forms previously employed in experimental and commercial spraying.

The weather conditions, being about average for the region, were only moderately favorable for an outbreak of apple scab. The principal primary infection period occurred at petal-fall when intermittent rains kept the foliage wet for about 50 hours. There were no important infection periods before this, but at least two slight ones occurred soon after.

The experiments were conducted in five commercial McIntosh orchards with the coöperation of the owners, the regular spraying crew and machinery of each place being used in making the applications. The orchards are designated as A, B, C, D, and E. Power sprayers of the usual type delivering from 250 to 350 pounds pressure were used in all but orchard B, where a Rex Liquiduster was employed. In this machine a small stream of liquid under low pressure is introduced into the air current from a blower, and thereby broken up into a mist.

Materials and Treatments.—Koppers flotation sulfur in all cases was delivered to the coöperating fruit growers in batches of exactly the amount required to make up a sprayer-load of the diluted material. The investigators obtained detailed records on each application, but were not always present when the spraying was done.

Koppers flotation sulfur paste was used at the rate of 10 pounds per 100 gallons, first stirred into a pail of water then poured into the sprayer tank as it was being filled. The dry wettable form of Koppers flotation sulfur was used at the rate of 5 pounds per 100 gallons, emptied slowly into the tank as it was being filled. Both forms went into suspension readily and exhibited no tendency to settle or clog nozzles. Lime sulfur was used at the rate of 2½ gallons of 32 degree Baume material per 100 gallons of dilute solution. Lead arsenate at the rate of 2½ or 3 pounds per 100 gallons was included in all applications.

Six applications of the test materials were made in orchards A, C, and E, two before bloom and four after. In addition, orchard E received an emergency sulfur dust application during the rainy

period just preceding the petal-fall spray, which was delayed a few days. Orchard D received seven applications of the test materials, the applications after bloom coming closer together than in orchards A, C, and E. Orchard B received nine applications with a Liquiduster, each from one side of the row only. When wind conditions permitted, the successive applications were from opposite sides of the trees.

With few exceptions, the lime-sulfur and corresponding flotation sulfur plots were sprayed on the same day with the same machinery and men, and under very similar weather conditions. There is no evidence that what exceptions did occur affected the results.

Plot layout.—The trees within each individual orchard were uniform, the orchards ranging from 14 to 26 years of age. The vigor was good in all but orchard B where it was poor. Each plot was of a size that easily could be sprayed with one tankful of material, and included at least 30 trees. In orchards A, B, and C, there was one plot of lime-sulfur and one of flotation sulfur. In orchards D, and E, plots 1 and 4 at the outsides of the experimental area received lime-sulfur, while the intermediate plots 2 and 3 received flotation sulfur. It was thought that the presence of lime-sulfur plots so located might indicate any trend in incidence of scab across the plots. No such trend was apparent. A single unsprayed check tree was left in each orchard, but check trees inadvertently received a small amount of drifting spray on a few occasions.

Trees were chosen for counts in such a way that the percentage of fruits with scab on a lime-sulfur tree could be compared with the percentage on an adjacent or nearby flotation sulfur tree which was as similar as could be selected in size, vigor, amount of crop, etc. Four such pairs of count trees were used for each pair of plots. They were well distributed over the respective experimental areas. The entire crop of each tree was examined.

Results

Effectiveness in scab control.—The results in apple scab control are summarized in Table I. It is apparent that good commercial control was obtained in all plots. The average percentage of fruits scabby for Koppers flotation sulfur paste is 1.3 while the average for the corresponding lime-sulfur trees is 0.3. The flotation sulfur paste gave slightly inferior scab control in 10 of the 12 pairs and equal control in the other 2 pairs.

The Student's odds that this difference is significant are 18:1. However, it seems probable that the men doing the spraying omitted an application on the flotation sulfur tree in pair 6. If pair 6 was eliminated, the average amount of scab on the other 11 trees receiving Koppers flotation sulfur paste would be 0.9 per cent, and for the corresponding trees receiving lime-sulfur, 0.3 per cent with odds of 207:1 that the difference is significant.

TABLE I—COMPARISONS OF LIME-SULFUR WITH TWO FORMS OF KOPPERS FLOTATION SULFUR IN APPLE SCAB CONTROL

Pair of Trees No.	Trees Sprayed with: Koppers Flotation Sulfur Paste, Total No. Fruits	Koppers Flotation Sulfur Paste, Per cent Scabby	Lime-sulfur, Total No. Fruits	Lime-sulfur, Per cent Scabby
	Orchard A (Scab on check 39 per cent)			
1	1,393	0.4	1,307	0.1
2	886	0.1	1,362	0.1
3	947	0.3	904	0.0
4	601	0.0	721	0.0
	Orchard B (Scab on check 70 per cent)			
5	770	1.9	689	0.9
6	1,016	6.0	1,354	0.1
7	597	1.8	650	0.6
8	1,158	2.6	1,067	1.0
	Orchard E (Scab on check 43 per cent)			
9	796	0.3	1,705	0.1
10	1,832	0.5	1,715	0.1
11	2,024	0.7	2,131	0.3
12	2,131	1.5	597[1]	0.5
Average.....		1.3		0.3

Pair of Trees No.	Trees Sprayed with: Koppers Flotation Sulfur, Dry Wettable, Total No. Fruits	Koppers Flotation Sulfur, Dry Wettable, Per cent Scabby	Lime-sulfur, Total No. Fruits	Lime-sulfur, Per cent Scabby
	Orchard C (Scab on check 7 per cent)			
13	1,196	1.8	2,057	0.2
14	2,263	2.7	2,257	0.4
15	1,512	2.4	2,262	0.1
16	2,144	0.6	1,348	0.3
	Orchard D (Scab on check 74 per cent)			
17	1,321	3.0	958	0.1
18	649	0.6	1,629	0.0
19	1,180	0.6	998	0.0
20	1,645	0.2	2,163	0.1
21	1,561	0.5	2,031	0.0
22	1,033	0.4	1,003	0.0
23	1,523	0.3	765	0.0
24	712	0.6	1,585	0.0
	Orchard E (Scab on check 43 per cent)			
25	1,827	1.1	1,719	0.3
26	2,902	0.6	2,766	0.3
27	1,054	0.2	1,400	0.5
28	1,598	0.6	2,347	0.1
Average.....		1.0		0.2

[1]Part of the crop of this tree was picked and lost before experimenters arrived.

The average amount of scab with Koppers flotation sulfur, dry wettable form is 1.0 per cent while the average for the corresponding lime-sulfur trees is 0.2 per cent. The Student's odds that this difference is significant are 555:1. The flotation sulfur paste is slightly inferior to lime-sulfur in scab control in 15 of the 16 pairs of count trees, while the reverse is true in one case.

There are too few instances in which the paste and the dry wettable form of flotation sulfur were used in the same orchards to permit of an accurate comparison of the two. However, they appear to have been about equally effective as judged by the results in orchard E and by the effectiveness of each relative to lime-sulfur. If all 28 pairs of trees in which lime-sulfur was compared with one of the forms of flotation sulfur are considered together, the odds that lime-sulfur was more effective are 2499:1. The average for lime-sulfur is 0.2 per cent scab, and for flotation sulfur, 1.2 per cent.

Foliage injury.—In orchards C and D, severe foliage injury occurred in the lime-sulfur plots. The injury was typical of that which often results from early applications of the combination of lime-sulfur and lead arsenate. Leaf margins were scorched, the ventral surfaces of the leaves became convex, and their growth was checked. Slight defoliation occurred in midsummer. No foliage injury occurred in the corresponding dry wettable flotation sulfur plots. The injury was clearly traceable to the pink and petal-fall sprays which were made in these particular orchards when foliage was moist and remained so for some time. No visible foliage injury occurred in the other orchards, and no fruit injury occurred in any of the plots.

It was apparent that the trees receiving Koppers flotation sulfur, either paste or dry wettable form, lost their visible residue more rapidly than did those receiving lime-sulfur treatments. This might be an advantage in late season, making possible more uniform color development. However, in the present tests, no outstanding differences in color at picking time were apparent, the last applications having been made to all plots about 2 months before harvest.

Discussion

It may be significant that the petal-fall application was made in all orchards after or near the close of the principal primary infection period of the year. In the light of previous work (1) and common knowledge it seems possible that results would have been more favorable to flotation sulfur had this application preceded the infection period. This would have been impossible, however, under the existing weather conditions, unless the application had been made while the trees were in bloom. The results are believed reliable for the particular conditions under which the experiments were conducted. Discretion must be exercised in their application, however, since the tests have been under way but a single year when scab was not extremely prevalent, since the differences in

scab control are small, and since it is not certain that a high degree of stability and uniformity had been attained in the manufacture of flotation sulfur fungicides. This last factor may help to explain variations in results obtained by different investigators with these materials.

The spray injury to foliage that occurred from pink and petal-fall applications emphasizes the fact that the frequent recommendation to substitute a milder fungicide for lime-sulfur *after petal fall* does not necessarily preclude all danger of injury. This recommendation should perhaps be supplemented with a suggestion of using a milder material also during early applications if moisture or temperature conditions are favorable for lime-sulfur injury.

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Some Results from Feeding Spray Chemicals to Albino Rats

By T. J. TALBERT and W. L. TAYLOE, *University of Missouri, Columbia, Mo.*

ABSTRACT

The complete paper will appear as Research Bulletin No. 183 from the Missouri Agricultural Experiment Station.

ARSENIC as arsenic trioxide or in the form of commercial lead arsenate, or calcium arsenate and lead acetate appears to affect albino rats as follows: Arsenic salts in quantities ranging from four to 200 times the official world tolerance (0.01 grain arsenic trioxide per pound of fruit) may promote activity, growth, and reproduction in the original stock for the first 23 to 25 weeks. Dosages of insecticides continued for more than 15 weeks decrease ability to raise young in the first generation. Arsenic did not appear to retard growth unless fed in quantities larger than 0.04 grain arsenic trioxide per pound of fruit. Lead as lead acetate and arsenic as lead arsenate, calcium arsenate, and arsenic trioxide appears to have injurious effects on albino rats only after prolonged feeding. Arsenic or lead, one or both, when fed in quantities larger than .04 grain for about 175 days seemed to have an injurious effect on the offspring by decreasing the weight and ability of the female to produce and rear young.

When these materials are fed daily over long periods in quantities of more than four times the world tolerance they have very markedly injurious effects on albino rats, and when the feeding is extended for 400 days the mortality rate increases and may amount to 35 per cent or more. Spray insecticides do not have as acutely toxic effects on albino rats as is generally supposed, even when used in amounts of 200 times the official world tolerance.

Our experience indicates that the insecticides in fruit sprays have, in fact, acute stimulating effects for the first 20 to 25 weeks, and injurious effects are brought on only when feeding is regular and prolonged, as shown in the feeding periods ranging from 378 to 497 days. Assuming that the spray chemicals have an effect upon man similar to that which they have had upon albino rats, it is the opinion of the authors that it is inconceivable for a human being to consume as spray residue on apples enough arsenic or lead at one time or over an extended period, even if abnormal quantities of heavily sprayed apples are eaten, to cause deleterious effects.

Some Effects of Thinning Fruits of Washington Navel and Valencia Orange Trees in California

By E. R. Parker, *Citrus Experiment Station, Riverside, Calif.*

ALTHOUGH small sizes of citrus fruits constitute a troublesome marketing problem in some years, very little is known about the conditions which cause them. Among the possible influences is the size of crop in the current crop year, and also the effect of size of crop in one year upon the fruit produced in the next.

Information upon these questions is derived with difficulty from field observations, and much of it is conflicting. There are many orange groves which annually produce large crops of consistently large or small fruits, with no evidence of a tendency towards alternate bearing. Correlation studies of individual trees in young, uniformly treated plantings destined to be used in fertilizer experiments (1) have not shown evidence of alternate bearing, although there is a possibility that it might have been masked somewhat by factors which caused positive interannual correlations in yields. On the other hand, certain orchards are known in which the entire crop does seem to alternate in different years, and there are indications that in these cases the average size of fruit is inversely related to the size of the crop. In some years, particularly since the crop year 1926–27, the entire California production of oranges of both varieties has tended to alternate in magnitude. Weather conditions have generally been satisfactory for the set and production of large crops from that date to the present time in all parts of the state. Prior to 1926–27 such a state-wide tendency has not been observed.

Experimental evidence upon the possible relationships between the volume of the crop and the size of the fruits produced is meager. Thinning has not been practiced, and only a few small trials have been made by growers. The only published results of experimental work which has been brought to our attention is that of Waynick (2, 3) who considered the practice to give negative results.

It appeared desirable to secure more detailed information on fruit thinning, particularly with mature trees. In the spring of 1930, there was a very heavy set of both Washington Navel and Valencia oranges followed by cool weather which resulted in a light "June" drop of young fruits. Seven orchards were selected for study at that time. Three, numbered 1 to 3, were of the Washington Navel variety, and were located in three typical districts where this variety is produced. All of the trees were 25 to 35 years old, were normal, and were known to be consistently good bearers. In orchard 3, however, there was a scattered amount of "off-bloom" fruit of larger size than the normal, which probably set during the fall of 1929.

Four productive Valencia orchards, located in typical Valencia districts, were likewise chosen for the study. Orchards numbered 4 and 5 were 25 to 35 years old, while orchards numbered 6 and 7 were 17 to 25 years old.

Approximately 30 trees in one part of each orchard were chosen for the trials. Such trees were as nearly uniform in size, vigor, and set of fruit as could be selected. These trees were then subdivided by rotation into three lots, A, B, and C, in such a way that a comparable sample was obtained for each group of approximately 10 trees. Lot C was designated as a check and was not thinned. Thinning was done on trees in lots A and B as soon as possible after the "June" drop was believed completed. In lot A an effort was made to remove every third fruit, and in lot B two out of three fruits, by snapping off the stems at the calyx. The fruits thinned from each tree were counted, and later count of the harvested fruit showed that the number of fruits removed was less than the desired one-third or two-thirds. The actual percentage removed in thinning is consequently reported. Measurements made of every tenth fruit removed from each thinned tree showed them to be quite uniform in size and to average from 36 to 42 mm in diameter.

At the time of harvesting the crop of 1930–31 the fruits from each tree were kept separate until their total volume was determined to an accuracy of $\frac{1}{10}$ of a field box (45 pounds). The number of fruits from each tree were then determined, and the diameter of every tenth fruit which was counted was measured. The measurements so obtained for each tree were grouped into a frequency distribution which was generally very normal in pattern. The mean of the measurements of the fruit from individual trees had a small probable error. The mean of the individual tree means was then taken as a measurement of the size of the fruit of the treatment. In each trial all of the fruit except that from orchard 6 from the approximately 10 trees in each lot was then combined and taken to a packing house and graded separately for size and quality of fruit.

It was also possible to make similar observations upon the crop produced by most of the experimental trees in the following season of 1931–32. The season of 1931–32 was also favored with satisfactory growing conditions, and good crops. The orchards observed were numbers 1 and 2 among the Washington Navels, and 5, 6, and 7, among the Valencias, although it was not possible to obtain the packing house data for the fruit of the experimental trees in orchard 6.

Certain results of these experiments are presented as graphs. The crop responses of the year in which the thinning was done, 1930–31, are indicated by solid lines, while the responses of the crop in the following year, 1931–32, are indicated in dotted lines. The results obtained are shown separately for each orchard, which

is indicated by number. In order to place the data for the various orchards on a comparable basis, most of the results are expressed in percentage of the response which was made by the unthinned trees for the year in question. Each point on these charts represents a determination made upon the fruit of the 10 trees.

Fig. 1 shows the mean diameter of Washington Navels in the three treatments of each experiment for the two seasons, in relation to the extent of thinning in 1930, as indicated by the per-

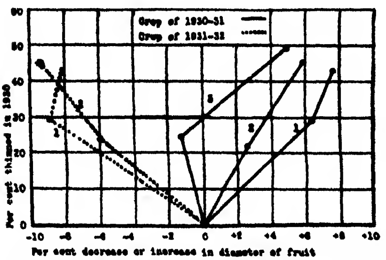

Fig. 1. Effect of thinning Washington navel oranges in 1930 on the mean diameter of the oranges harvested, in per cent of the mean diameter of the fruits of the unthinned trees.

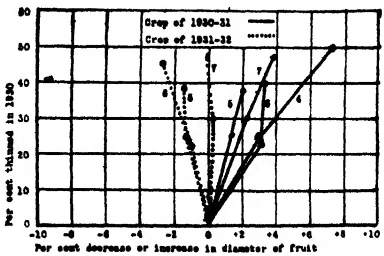

Fig. 2. Effect of thinning Valencia oranges in 1930 on the mean diameter of the oranges harvested, in per cent of the mean diameter of the fruits of the unthinned trees.

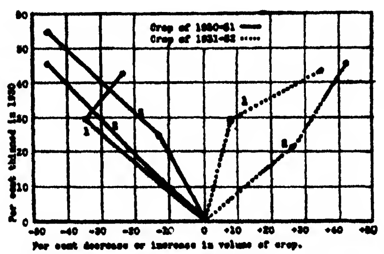

Fig. 3. Effect of thinning Washington navel oranges in 1930 on the volume of crop harvested in per cent of the crop harvested from the unthinned trees in the same years.

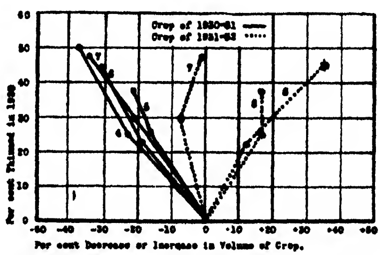

Fig. 4. Effect of thinning Valencia oranges in 1930 on the volume of crop harvested in per cent of the crop harvested from the unthinned trees in the same years.

centage increase or decrease over the mean diameter of the fruits of unthinned trees. In every case but one the thinned trees produced larger fruit in 1930–31 than did the control trees and the size of fruit of the thinned trees increased with the greater thinning. In the following year, however, the two orchards studied produced smaller fruit on the trees thinned in 1930 than on the unthinned control trees. The trees in experiment 3 are less uniform than those in the other two navel orchards, as indicated by measurements of trunk circumference.

The effect of thinning on diameter of Valencia oranges is shown in Fig. 2. In each experiment the solid lines show that the size of the fruit was increased in the year of thinning and that the heavier thinning resulted in the larger fruit. In the following year two out of the three orchards studied showed that the thinning in 1930 resulted in smaller sizes. There is evidently a tendency for thinning to produce larger fruit in the season in which the thinning is done

with both varieties of oranges, followed in the succeeding season by a reaction in the opposite direction. In the one orchard which showed no effect the trees were 17 years old in 1932. Also, some influence affected this orchard relatively more favorably in 1931–32 than in the previous year, for the average production of the unthinned trees increased 27 per cent over that in 1930–31, while the yield of control trees in orchards numbered 5 and 6 decreased in the second year.

Fig. 3 shows that with the Washington Navel the total crop picked in the year of thinning was reduced by the practice. In all but one case this reduction took place in relation to the severity of thinning. The increase in size of fruit which was obtained was not sufficient to offset the reduction in numbers of fruit harvested. In the following season, 1931–32, however, the two orchards studied showed that the thinning in 1930 resulted in a very definite increase in the volume of fruit picked.

In the case of Valencias, Fig. 4, similar results were obtained in the year of thinning,—a reduction of total crop in relation to the amount of fruit removed. In the following season two of the orchards observed showed that the trees which were thinned in 1930 produced heavier crops of fruit than did the unthinned control trees. The younger orchard, number 7, showed differences as a result of thinning which are so small that they are probably not significant.

The effect of thinning in 1930 upon the number of fruits matured in the following crop year, 1931–32, for the Washington Navel variety is shown in Fig. 5. A pronounced relationship is evident in the two trials where such observations were made. A reduction of about 45 per cent in the number of fruits which were permitted to mature in 1930–31 resulted in an increase of nearly 80 per cent in the number matured in 1931–32 in one orchard, and of about 105 per cent in the other.

In the case of Valencias, Fig. 6, the reduction of the number of fruits by thinning resulted in an increase in the number matured the next season in two out of three experiments. The effect was not so marked as with the navels, however, Experiment number 7 failed to show a definite relationship between the extent of thinning and the number of fruits matured in the next crop year.

Due to the small sizes of the fruits at the time of thinning it was necessary to remove them at random, with the exception of breaking the infrequent clusters. It is important to know if this type of thinning has increased or decreased the amount of fancy grade fruit, as judged at the packing house. In Fig. 7 the number of fruits of this grade are shown for each treatment in each experiment with Washington Navel oranges.

The number is expressed as per cent of the total number of fruits harvested in each lot. It will be noticed that there is a big difference in the amounts of fruit of this grade in the different ex-

periments as well as in the two years at the same location. There does not, however, appear to be any relationship between the amount of fruit thinned and the proportion of fancy fruit harvested, either in the crop year in which the thinning was done or in the subse-

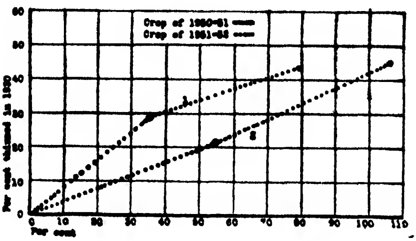

Fig. 5. Effect of thinning of Washington navel oranges in 1930 on the number of oranges harvested in 1931-32 from the same trees in per cent of the number harvested from unthinned trees in the same year.

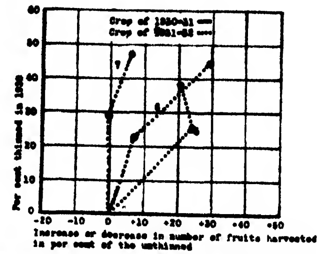

Fig. 6. Effect of thinning Valencia oranges in 1930 on the number of oranges harvested in 1931-32 from the same trees in per cent of the number harvested from unthinned trees in the same year.

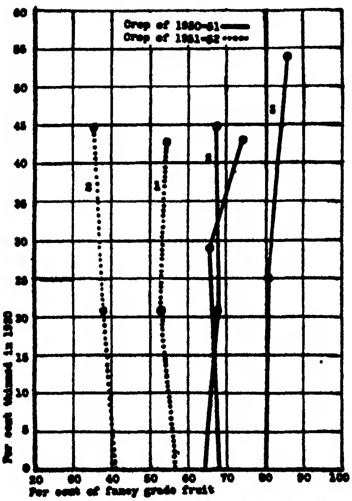

Fig. 7. Relation of extent of thinning of Washington navel oranges to per cent of fruits of fancy grade in the year of thinning and the next year.

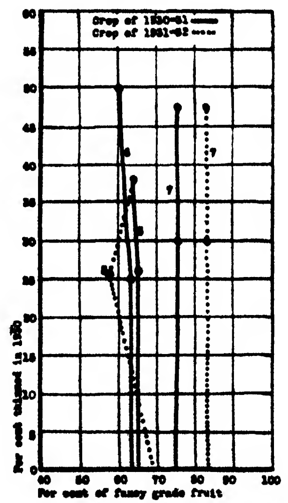

Fig. 8. Relation of extent of thinning Valencia oranges to per cent of fruits of fancy grade in the year of thinning and the next year.

quent year. With the Valencia variety, Fig. 8, there likewise was no effect of thinning upon the relative number of fancy grade fruits harvested in either year.

These experiments indicate a definite response to the thinning, after the "June" drop, of both Washington Navel and Valencia oranges. This effect was manifested in the larger size of fruits harvested in the year of thinning and a reduction of total crop. In the year following, a larger crop was picked from the thinned trees than from the control trees. Although the mean size of the fruits was smaller there were many more of them. There is apparently a marked tendency for the reduced crop in the year of thinning to

be compensated for the next year. This is shown in Table I where the results for each treatment for the 2 years are averaged together for the five experiments which ran over a 2-year period. Each entry represents the annual mean of approximately 50 trees for the 2 years. The equality in the mean number of oranges harvested annually per tree, mean size of the oranges, and the mean number of boxes picked per tree is remarkable.

TABLE I—SUMMARY OF THE EFFECT OF THINNING IN 1930 ON CROPS OF 1930–31 AND 1931–32[1]

	Unthinned	Lightly Thinned	Heavily Thinned
Mean[2] number oranges harvested annually per tree	993	903	924
Mean[2] diameter of oranges harvested, mm	66.75	66.76	66.80
Mean[2] number boxes of fruit picked per tree	6.59	6.24	6.29

[1]Includes all experiments which were carried out for 2 years, with both Washington Navel and Valencia varieties.
[2]Giving equal weight to each tree in each treatment plot, annually, and to each treatment plot in each experiment each year.

It is probable that this pronounced effect of one crop of oranges upon the next should frequently be considered in studies of the metabolism of mature orange trees. Whether or not the practice of thinning fruits has any commercial application would seem to depend in a large measure upon the returns for fruits of different sizes in various years, and also upon a number of special considerations.

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Starch in the Young Orange Tree

By S. H. Cameron, *University of California, Los Angeles, Calif.*

IN an earlier paper (1) certain conclusions regarding storage of starch in pear and apricot trees were presented. As a continuation of this type of investigation, a study of starch storage in certain evergreen and deciduous subtropical fruit species was undertaken. The conclusions reported in the present paper apply specifically to the young orange tree, although a second series of observations made on material collected at bi-weekly intervals from a 12-year-old orange tree, confirm and extend the conclusions reached for the younger trees.

Materials and Methods

Fifteen young Valencia orange trees, 3½ years old at the time collections were started, were used. The trees were in excellent condition, very uniform in size and vigor, and bearing an average crop of fruit. Samples were collected at Riverside, California, on 13 different days, at intervals of approximately 3 to 5 weeks, between September 1, 1925, and August 3, 1926. The whole tree, including as much of the root system as it was possible to save, was collected and preserved for study. Each tree was divided into 12 fractions and 14 sub-fractions. Both microchemical and macrochemical methods were employed in determining fluctuations in starch content. Certain constituents other than starch were determined macrochemically but will not be considered at this time. Conventional methods were used for the michrochemical study. The technique used for the quantitative determinations was briefly as follows: The material was dried, ground, extracted with benzene, and extracted with 95 per cent alcohol; the starch in the residue liquified with saliva, hydrolized with HCl, and determined as glucose by the picric acid method, using essentially the procedure outlined by Willaman and Davison (4).

Analytical Data and Microchemical Observations

Space does not permit nor is it necessary to present all of the analytical data. In the accompanying table data indicating variations in starch and moisture content of representative portions of the tree are presented.

In general they show that except in root-bark, fluctuations in starch content were not marked. Following a minimum in July (in the branches) and August (in the trunk and roots) there was a gradual increase in starch content to a maximum in early spring, then a gradual decrease to the minimum in July and August. An inverse relationship between moisture and starch content is indicated.

So far as starch content is concerned the microscopic study which preceded the quantitative determinations furnished considerably more information as to what the actual situation in the plant was than did

TABLE I—SEASONAL VARIATION IN STARCH AND MOISTURE CONTENT OF CERTAIN FRACTIONS OF YOUNG ORANGE TREES

Fraction	Sept. 1	Oct. 1	Nov. 1	Dec. 3	Jan. 4	Jan. 26	Feb. 15	Mar. 6	Apr. 8	May 4	June 1	July 8	Aug. 3
	Expressed as Per cent of Fresh Weight												
	Starch												
Leaves	0.66	0.75	1.96	1.09	2.30	Lost	2.96	2.23	1.39	1.63	0.71	0.70	0.66
Fruit wood (twigs)	2.50	2.71	4.58	3.84	4.94	4.01	5.84	3.64	2.21	2.20	1.57	1.48	2.10
Lateral branch													
Bark	2.16	1.51	3.40	2.79	3.58	2.82	4.95	3.57	2.65	2.84	1.65	1.40	1.51
Wood	2.84	3.28	4.27	3.45	4.25	3.30	6.10	4.42	2.92	3.23	2.07	1.96	2.42
Scaffold branch													
Bark	1.42	1.58	2.48	2.16	2.10	2.01	3.23	2.59	1.79	1.76	1.43	1.33	1.64
Wood	1.85	2.09	4.19	3.50	3.62	2.85	4.61	3.55	3.50	3.48	1.52	2.12	1.87
Trunk													
Bark	1.58	1.65	2.88	2.10	2.20	1.68	2.54	2.03	1.47	1.48	1.36	1.68	1.57
Outer wood*	2.01	3.31	4.12	3.12	3.66	3.21	3.90	3.18	3.12	3.19	2.24	1.69	1.34
Inner wood†	3.55	3.55	5.16	4.94	5.21	4.85	4.85	4.86	5.75	5.64	4.98	4.61	4.07
Large root bark	2.42	1.68	5.90	6.38	7.71	8.90	12.54	13.66	8.50	8.51	6.13	2.65	1.61
Wood	2.64	2.89	4.45	3.86	4.29	5.08	5.90	5.00	3.88	4.89	3.55	3.23	2.36
Small root bark	2.04	2.85	9.18	10.53	9.01	10.13	14.37	13.45	10.03	11.58	7.57	3.34	1.94
Wood	2.12	2.36	4.05	4.48	3.88	4.51	5.84	5.17	3.98	5.69	4.35	2.89	2.09
	Moisture												
Leaves	66.2	64.1	59.0	59.2	59.0	Lost	59.2	58.4	59.6	59.4	63.0	59.8	60.5
Fruit wood (twigs)	55.3	54.8	52.4	50.4	50.5	51.6	52.2	56.0	60.5	57.3	60.3	54.3	50.5
Lateral branch													
Bark	59.7	60.4	58.9	57.0	56.3	59.4	55.0	58.2	62.2	64.5	64.2	61.1	60.4
Wood	38.1	38.9	37.7	35.6	34.7	36.1	32.5	35.9	39.0	39.8	42.4	38.1	34.7
Scaffold branch													
Bark	62.7	64.2	61.8	59.7	57.7	59.4	55.6	60.0	61.2	64.6	63.9	59.9	58.6
Wood	41.6	41.9	38.9	37.5	35.4	36.5	32.8	36.5	37.5	40.4	39.6	38.0	36.0
Trunk													
Bark	64.2	61.9	60.2	60.8	60.0	60.3	56.5	62.2	61.4	63.9	63.2	59.0	60.2
Outer wood*	49.2	47.5	43.1	44.3	42.1	42.7	39.8	43.3	45.5	45.3	45.3	43.8	46.4
Inner wood†	40.8	39.3	37.3	38.4	37.1	37.3	37.4	37.2	37.6	36.7	37.8	36.4	37.2
Large root bark	73.6	73.3	68.0	66.9	63.3	61.6	54.8	59.0	61.3	65.0	68.2	68.8	71.5
Wood	48.9	47.2	42.7	43.5	40.7	40.5	37.5	39.6	41.8	40.9	42.4	42.3	44.3
Small root bark	74.3	72.3	63.7	59.4	61.1	58.5	51.6	54.7	58.9	58.2	63.9	67.8	70.7
Wood	59.0	54.4	50.8	49.4	46.4	47.4	44.3	43.9	46.8	43.1	45.6	46.6	49.1

the quantitative data. Two reasons may be suggested for this; namely, (1) the sampling was so gross that minor fluctuations in starch content were obscured by the large bulk of tissue included in the sample; (2) except for comparing similar fractions of different trees no basis on which the results may be calculated is sufficiently uniform to justify the drawing of conclusions with any degree of certainty.

The michrochemical observations indicated that fluctuations in starch content were confined mainly to the tissues adjacent to the cambium. Following the resumption of growth activity in the spring, starch disappeared from the phloem parenchyma of twigs and small branches, later a marked reduction in starch content of the outer xylem and cortical regions was observed. These tissues together with the pith and medullary rays appear to constitute the main storage tissues. Wood parenchyma is of the vasicentric type and is comparatively limited in amount. It is confined almost entirely to the region immediately adjacent to the vessels and to rings or partial rings apparently laid down toward the end of a season or cycle of growth. Presumably because of its proximity to the tracheae, appearance and disappearance of starch in the wood parenchyma was comparatively rapid. Very little change in starch content was observed in the outer cortex, pith, and inner xylem of the older parts of the tree.

Considering the tree as a whole, disappearance of starch progressed basipitally. Although collections were not made frequently enough for one to decide with certainty there appeared to be an interval of from 4 to 6 weeks between disappearance from the small branches and an evident reduction in starch content of the roots. Redeposition of starch appeared to follow the same sequence as its disappearance. It accumulated first in regions adjacent to the leaves, later in the branches, trunk and roots.

Discussion

There appears to be quite general agreement among investigators that in the phloem and cortex of twigs and branches of all trees in regions of severe winter climate and of deciduous trees in regions of mild winter climate, starch accumulates through the summer and autumn, diminishes to a minimum or disappears in winter, reappears in large quantity in early spring and diminishes to a second minimum as the buds are unfolding. In the xylem of some trees starch changes are analogous to those in the phloem and cortex, in others starch remains unchanged or only slightly diminished throughout the winter.

That a different state of affairs obtains in evergreen trees in regions of mild winter climate is indicated by the present investigation and that of du Sablon (2) both of which show a constant increase in reserves during the autumn and winter. A maximum is reached in early spring just preceding blossoming and the resumption of growth activity. Following this there is a gradual decrease to a minimum in late summer or early autumn.

With respect to changes in starch content the orange tree appears to resemble that group of deciduous trees in which starch remains practically unchanged in the xylem. The most striking fluctuations observed in the older portions of the tree were in the phloem parenchyma, cortex, and xylem adjacent to the cambium. In the central portion of the main roots and in the pith and adjacent xylem of the trunk and large branches, little change in starch content was noted. Some fluctuation is indicated in these regions by the analytical data. However, this is probably more apparent than real resulting from the inclusion in the fraction of considerable xylem from near the cambium in which fluctuations were evident.

Fluctuations in starch content were very gradual in comparison with those which occur in deciduous species. At no time was there a sudden appearance or disappearance of starch such as occurs in deciduous species during the blossoming and leafing out period. The orange trees blossomed profusely in the spring and characteristically produced three flushes or cycles of growth during the growing season. However, except in the twigs and small branches the effect of this growth activity on starch content was slight.

An inverse relationship between moisture and starch content is indicated by the quantitative data. The maximum moisture content occurred in late summer and early autumn coincident with a minimum starch content. That a part of the fluctuation in moisture content may be more apparent than real seems evident since in some fractions changes in starch are almost sufficient to account for the inverse changes in moisture content. In other fractions these fluctuations appear to be greater than can be accounted for by changes in starch content. There still remains the possibility that these apparent fluctuations may be due to variations in other constituents such as the hemicelluloses which were not determined. Attention has been called to this inverse relationship between moisture and carbohydrates by others, notably du Sablon (2) and Hooker (3).

The fact that there is an apparently significant increase in starch content of the leaves during the autumn and winter suggests the possibility of their functioning as storage organs. Representing as they do approximately 25 per cent of the total fresh weight of the tree, they may constitute an effective reservoir for reserve substances.

That the presence of leaves throughout the year to a considerable degree accounts for the difference in behavior of evergreen and deciduous trees so far as starch storage is concerned can hardly be doubted. There is considerable evidence in support of the belief that, in regions of mild winter climate, assimilation may continue in leaves of evergreen plants, throughout the winter, though possibly at a slower rate than during the summer, while during the same period growth activity is suspended or at a minimum. As a consequence the utilization of elaborated materials is slight and they accumulate as reserves.

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Somatic Segregation in a Sectorial Chimaera of the Bartlett Pear

By V. R. GARDNER, J. W. CRIST, and R. E. GIBSON, *Michigan State College, East Lansing, Mich.*

ABSTRACT

The original paper is to be published in a forthcoming issue of the Journal of Agricultural Research.

THERE is described a sectorial chimaera of the Bartlett pear from which has been segregated two color forms and two forms differing from each other in shape of fruit. Segregation as to color of bark and skin of fruit is independent of segregation as to shape of fruit. The evidence indicates that continued selection is necessary properly to maintain, as well as to isolate, the types resulting from segregation.

Fruit and Leaf Characters in Inter-specific Hybrids of Prunus[1]

By Ernest Angelo and W. H. Alderman, *University of Minnesota, St. Paul, Minn.*

DURING the summers of 1931 and 1932 a study was made of the leaf and fruit types of several hundred seedling plum trees growing on the University of Minnesota Fruit Breeding Farm. The seedlings are from controlled crosses of various species. The purpose of the study was to determine the order and manner of grouping the seedlings into the different leaf and fruit types.

The classification was based upon qualitative characters alone. Plants bearing leaves resembling those of the Americana species were classed as such, while those bearing leaves of the Salicina type were classed as Salicina. Plants bearing leaves intermediate between the species types were classed as intermediate. Some trees bore leaves which could not be classified in any of these groups; these were grouped as undetermined. Those trees bearing fruit were classified in the same manner for this character.

The data are presented here in summarized tables. Results of reciprocal crosses are shown in separate groups. Table I shows the segregation into the various leaf and fruit types of the progeny from a cross of the two species, *Prunus salicina* and *P. americana.*

TABLE I—Summary of F_1 Populations Involving *Prunus salicina* and *P. Americana*

Cross	Population	Per cent Grouped as			
		Americana	Inter-mediate	Salicina	Un-determined
		Foliage Types			
P. salicina x *P. americana*	302	27.1	41.4	30.5	1.0
P. americana x *P. salicina*	164	56.7	24.4	15.8	3.0
		Fruit Types			
P. salicina x *P. americana*	100	34.0	54.0	10.0	2.0
P. americana x *P. salicina*	21	47.6	42.8	9.6	0.0

This being an F_1 population, we should expect the plants to show intermediate leaf and fruit characters. However, the data show that of 302 individuals from a cross of salicina x americana, 27.1 per cent are of the americana leaf type, 41.4 per cent are of the intermediate, 30.5 per cent are of the salicina type, and 1.0 per cent of the undetermined leaf type. In the reciprocal cross, americana x salicina,

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from a population of 164 individuals, 56.7 per cent are of americana leaf type, 24.4 per cent are of the intermediate, 15.8 per cent of the salicina type, and 3 per cent of the undetermined leaf type. Both parental and intermediate fruit types have also appeared in the progeny on trees which have fruited.

In Table II are summarized the foliage types resulting from the reciprocal crosses of *Prunus nigra* and *P. salicina*. In the cross *P. nigra* x *P. salicina* with a small population of 25, no salicina type individuals occurred but there were 76 per cent of nigra and 24 per cent of intermediate leaf type. Of 46 reciprocal crosses of these two species 21.7 per cent were of nigra, 41.3 per cent were intermediate, and 37.2 per cent were of the salicina leaf type. Very few of these trees were fruiting. Comparing the reciprocal crosses shown in Tables I and II the data show that the percentage of parental types in the progeny is influenced by the species used as the maternal parent. For example, with *P. salicina* as the maternal and *P. americana* as the paternal parent, 30.5 per cent of the progeny are of the salicina type, and 27.1 per cent of the paternal type, while in the reciprocal, with *P. americana* as the maternal parent 56.7 per cent are of the maternal type and 15.8 per cent are of the paternal type. There appears to be some maternal influence exerted by the maternal parent on the F_1 progeny.

TABLE II—SUMMARY OF F_1 POPULATIONS INVOLVING *Prunus salicina* AND *P. nigra*

Cross	Population	Per cent Foliage Types Grouped as			
		Nigra	Intermediate	Salicina	Undetermined
P. salicina x *P. nigra*	46	21.7	41.3	37.2	0.0
P. nigra x *P. salicina*	25	76.0	24.0	00.0	0.0

Normally one would expect nothing but intermediate types to result from crossing two pure species. In one study of crosses made among americana, nigra, and salicina, we find that the F_1 progeny segregate into the parental types as well as the intermediate. No explanation is offered for this behavior but it is suggested that the characters studied, namely, leaf and fruit types, may be so extremely heterozygous in the species used as to produce the groupings obtained in the F_1. Hedrick, in his "Systematic Pomology," suggests that the American and Japanese species of plums are probably closely related, pointing out the similarity of the trees in general aspect and the similarity in leaf types, fruits, vernation, and manner in which buds are borne. This close relationship, together with the heterozygous nature of the species, may assist in explaining the abnormal grouping occurring in this study.

Table III shows the grouping into the various leaf types of an F_2 population of 163 individuals from a cross of (*Prunus salicina* x *P. americana*) x (*P. salicina* x *P. americana*). Here both parental types

TABLE III—SUMMARY OF F_2 POPULATIONS INVOLVING *Prunus salicina* AND *P. americana*

Cross	Population	Per cent Foliage Types Grouped as		
		Americana	Intermediate	Salicina
(*P. salicina* x *P. americana*) x (*P. salicina* x *P. americana*)	163	7.5	25.7	66.9

and the intermediate type appear, but there is a much larger percentage of the salicina type, namely, 66.9 per cent as compared with 7.5 per cent of the americana. It is evident that, since in the F_1 of these species the grouping is very similar to that in the F_2, the practical fruit breeder may obtain all types in the F_1 without the loss of additional time and expense involved in developing an F_2 population.

Self and Cross Sterility in Plum Hybrids[1]

By W. H. ALDERMAN and ERNEST ANGELO, *University of Minnesota, St. Paul, Minn.*

SELF-STERILITY is so common in the plum that it generally is accepted as the prevailing condition, though some noteworthy exceptions occur, as in several varieties in *Prunus domestica*. In Minnesota and other states of the upper Mississippi Valley the plums grown are largely hybrids of the oriental species *P. salicina* and *P. Simonii* combined in simple and complex hybrids with native species; namely, *P. americana*, *P. nigra*, *P. hortulana Mineri* and *P. Besseyi*. In addition to these is a considerable number of cultivated varieties representing the native species in the pure form. Both native and hybrid varieties are uniformly self-sterile, even when grown under as nearly optimum conditions as may be provided in a greenhouse.

The Minnesota Station has introduced from its Fruit Breeding Farm several hybrid varieties which have been widely planted in both home and commercial orchards. Since self-sterility was assumed, growers were advised to combine in their plantings three or more varieties to provide for cross pollination. Even where this had been done the number of cases of unsatisfactory set of fruit reported aroused suspicion of a high degree of cross sterility in these hybrids, though many of them had intercrossed successfully in breeding experiments in the greenhouse.

Unfavorable weather conditions in 1930 and 1931 prevented securing reliable experimental data until 1932. Nearly all combinations of intercrosses were made between seven of the leading varieties. Five of these were simple hybrids of *Prunus salicina* and *P. americana* or *P. americana mollis;* and two, Underwood and La Crescent, were complex hybrids resulting from a cross of *P. americana* with Shiro, a Luther Burbank production containing blood of *P. simonii, P. salicina* and probably *P. cerasifera* and *P. Munsoniana*. In addition, the seven varieties were pollinated with Surprise, a variety of *P. hortulana Mineri;* with two varieties of *P. americana,* De Soto and Rollingstone; with Wolf, a variety of *P. americana mollis;* and with three hybrids, Hanska, Kaga, and Superior (Minnesota 194). The last named varieties derive ½ or ¼ of their genetic constitution from *P. Simonii*. Of these, Kaga had been used successfully in greenhouse crossing.

All the 1932 tests were made in the orchard with weather conditions favorable except for abnormally high temperatures which reached about 90 degrees F as a maximum, and shortened the blossom season. Branches carrying from 300 to 600 blossoms were covered with fine meshed cheesecloth just before the flowers opened. Pollen was secured from branches with unopened flowers brought into the green-

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house where anthers were removed soon after the opening of the petals and dried slightly at room temperature to cause them to dehisce. Pollen was separated from other stamen material by screening through a wire sieve. Since all varieties in the test were self-sterile, emasculation was considered unnecessary and the pollen was applied directly to the stigmas by means of camel's hair brushes which were sterilized in alcohol after each operation to prevent contamination of the pollen. All blossoms on the branches selected were pollinated; the total number of pollinations exceeded 43,000. The records of fruit set were taken soon after the June drop and before appreciable accidental loss from wind or other agencies might occur. Since an occasional fruit may fall normally after the June drop is apparently completed, the percentages of set here recorded may be slightly too high, but the error is not great enough to influence materially the values given.

The data in the accompanying table indicates clearly that the effectiveness of a pollenizer varies on different varieties and that it will

TABLE I—PER CENT OF FRUIT SET AS INFLUENCED BY POLLEN VARIETY, 1932

Variety Pollenized	Most Effective Pollenizers			Fair Pollenizers			Poor Pollenizers		
	Variety	No. Bloom	Per cent Set	Variety	No. Bloom	Per cent Set	Variety	No. Bloom	Per cent Set
Elliot	Superior	555	2.7				Rollingstone	334	.6
	Surprise	208	2.4				Wolf	554	.4
							Hanska	580	.3
							Underwood	654	.3
							Red Wing	345	.3
							Tonka	124	.0
							Kaga	496	.0
							De Soto	170	.0
							Monitor	128	.0
							La Crescent	328	.0
La Crescent	Wolf	351	12.3				Red Wing	527	.6
	Surprise	613	9.8				Elliot	482	.4
	De Soto	358	5.9				Superior	535	.4
	Rollingstone	620	4.5				Monitor	510	.2
							Underwood	531	.0
							Hanska	435	.0
							Tonka	275	.0
							Waneta	343	.0
Monitor	Surprise	330	15.8	Kaga	762	1.7	Underwood	622	.6
							Tonka	520	.4
							Hanska	526	.4
							Red Wing	362	.3
							La Crescent	516	.2
							Elliot	732	.0

TABLE I—*Continued*

Variety Pollenized	Most Effective Pollinizers			Fair Pollinizers			Poor Pollenizers		
	Variety	No. Bloom	Per cent Set	Variety	No.	Per cent Set	Variety	No. Bloom	Per cent Set
Red Wing	Rolling-stone	270	16.7	Hanska	206	2.9	Monitor	521	
	Surprise	259	13.5	Kaga	251	1.6	La Cres-cent	342	.6
	Wolf	424	13.2	Superior	491	1.2	Under-wood	361	.6
	De Soto	373	7.8	Elliot	178	1.1	Tonka	277	.4
Tonka	De Soto	533	12.8	Hanska	654	1.8	Superior	456	.7
	Wolf	631	8.4	Under-wood	303	1.0	La Cres-cent	290	.3
	Rolling-stone	319	8.2	Kaga	319	.9	Monitor	230	.0
	Surprise	305	5.6				Red Wing	510	.0
							Elliot	237	.0
Under-wood	Hanska	686	2.9	Rolling-stone	517	1.2	Wolf	990	.7
							Red Wing	527	.4
							Superior	931	.3
							Kaga	634	.2
							Elliot	800	.0
							La Cres-cent	682	.0
							De Soto	579	.0
							Tonka	652	.0
							Monitor	810	.0
							Waneta	354	.0
Wan-eta	Surprise	196	9.7	Rolling-stone	510	2.2	Red Wing	158	.6
	Hanska	512	4.5	Wolf	535	1.9	Tonka	256	.0
				De Soto	346	1.7	Monitor	181	.0
				Superior	426	1.4	Under-wood	416	.0
				Kaga	544	1.3			

be difficult, if not impossible, to find a universal pollenizer which gives satisfactory set on all varieties of the Oriental-American hybrids grown commonly in the upper Mississippi Valley. In the limited test of 1932, Surprise most nearly qualified for this position, being listed in the "most effective pollenizer" group for all varieties on which it was tested, but this variety ranged from 2.4 per cent set in Elliot to 16.7 per cent in Red Wing. A very satisfactory commercial crop will follow a set of from 4 to 6 per cent of the flowers produced. The data in the table most strikingly illustrate the almost complete worthlessness of the seven hybrid varieties studied when used as pollenizers for one another. On the other hand, the native varieties, Surprise, Rollingstone, De Soto, and Wolf are, with a few exceptions, fair to good pollenizers wherever used.

The three hybrids used as pollenizers only, Hanska, Kaga, and Superior (Minnesota 194), were much more effective than any of the original seven among which intercrosses were made. A possible explanation of this difference may lie in the fact that these were de-

veloped in part from the Chinese apricot-plum, *Prunus Simonii*. Hanska and Kaga derive half their genetic composition from this species and Superior (Minnesota 194) gets ¼ its blood lines from the same source; Underwood and La Crescent carry a trace of the same species and Underwood at least is rated as a fair pollenizer in one instance. The only hybrids listed in the groups of "most effective" or "fair pollenizers" are those carrying some degree of *Prunus Simonii* inheritance. It is hoped that further search among hybrids of this species will reveal satisfactory pollenizers for the varieties used in commercial orchards. Effective pollenizers among the group of Oriental-American hybrids, would be particularly desirable, not only because they produce more valuable fruit than the native species, but because of the tendency of the hybrid varieties to bloom at about the same time. The native varieties blossom later than the hybrids when grown south of the approximate latitude of southern Minnesota. North of this point the blossoming seasons of all plums tend to overlap, and varieties of native species can doubtless be used successfully as pollenizers.

Studies of Pollen Germination in Certain Species and Interspecific Hybrids of Prunus[1]

By Catharine L. Becker, *University of Minnesota, St. Paul, Minn.*

UNSATISFACTORY yields of the hybrid plums commonly grown in Minnesota, in spite of supposedly sufficient provisions for cross pollination as frequently reported by commercial growers, indicated the possibility of an unexpected degree of cross sterility. Since this cross sterility appeared more pronounced when cold weather occurred during the blossoming period, ability of pollen of different varieties to germinate and grow at low temperatures was studied.

The germination medium used was a thin layer of a gel of 1 per cent shred agar, 15 per cent granulated beet sugar, and a trace of sterile yeast, in a petri dish. A sterile needle was used to spread the pollen thinly on the surface of the agar. Pollen was incubated 24 hours in constant temperature chambers at 0, 5, 10, 13, and 20 degrees C.

A magnification of 20 diameters was used in determining per cent of germination and a magnification of 80 in measuring pollen tube length. Pollen tubes could be accurately measured to 10 microns Probable errors were calculated from the formula:

$$\text{P. E.} = .6745\sqrt{\frac{\Sigma x^2 - \Sigma x \bar{x}}{N(N-1)}}$$

Viability

Most of the Minnesota hybrid plums produce abundant pollen. The varieties Elliot and Monitor, however, produce only moderate amounts. Roughly half of the pollen grains of the varieties Elliot, LaCrescent, Monitor, Red Wing, and Tom Thumb were empty and remained shrunken on the germination medium. Other hybrid varieties apparently produced high percentages of good pollen. Empty grains were rare among the pollen of varieties of the native species.

A number of tests were made of the viability of pollen of different varieties, using both fresh pollen and pollen that had been kept up to 7 days. A total of 3,000 to 8,000 pollen grains of each variety of the hybrid plums, except Elliot and Tonka, were tested. Only 500 pollen grains of Elliot and 400 pollen grains of Tonka were incubated. Pollen of the hybrids was low in viability. Elliot, LaCrescent, Monitor, Red Wing and Underwood produced pollen germinating one per cent or less. Four pollen grains in 4,700 of Monitor germinated, and two pollen grains among 3,800 of La-Crescent produced pollen tubes.

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Fiebing, Radisson, Tonka, Superior (Minnesota 194) and Minnesota 195 produced slightly better pollen, though the germination was always below 5 per cent for all except Tonka, of which only one test was made. Ten-day-old pollen of Tom Thumb failed to germinate at all, though 3,100 grains were tested, but Nicollet pollen germinated 5 per cent of 1,800 grains. It is evident that none of these hybrids can be dependable pollenizers. A few may be moderately successful pollenizers under optimum conditions.

Varieties of the native plums produced only fair pollen. The average germination at room temperature of 5- to 7-day-old pollen was 8.1 per cent of 2,200 grains of Assiniboin, 10.2 per cent of 1,000 grains of De Soto, 8.0 per cent of 2,000 grains of Rollingstone, 11.2 per cent of 1,000 grains of Surprise, and 14.3 per cent of 1,000 grains of Wolf.

Fresh pollen of the black cherry, *Prunus serotina,* germinated 26.3 per cent.

Effect of Temperature on Per Cent of Germination

Pollen of the plums and sand cherry hybrids did not germinate in 24 hours at 5 degrees C. At 10 degrees C germination of all varieties used was below that at higher temperatures. The tubes were still very short at the end of 24 hours and many grains which had not germinated did so if the incubation period was prolonged. The per cent of germination varied considerably from one test to another, and though the pollen was slower to germinate at 13 than at 20 degrees C, there was no consistent difference in per cent of germination between these two temperatures.

Pollen of *Prunus serotina* germinated in 24 hours at 5 degrees C, but not at 0 degrees C. The percentage did not appear to be influenced by temperature through the range 10 to 32 degrees C. Germination of fresh pollen at these temperatures ranged from 15 per cent of 500 in one culture to 41 per cent of 100 in another. Below 10 degrees C the rate of germination was too slow to allow all viable pollen to form tubes within 24 hours, and above 32 degrees C, at 36 and 40, many grains swelled too fast and burst without germinating.

Effect of Temperature on Rate of Pollen Tube Growth

Rate of pollen tube growth is markedly influenced by temperature. Twenty tubes were measured at random from each culture incubated 24 hours. Table I shows the average length of pollen tubes obtained at 10, 13, and 20–21 degrees C, with the varieties Assiniboin, De Soto, Rollingstone, Surprise, Wolf, and Nicollet.

At 10 degrees C, the lowest temperature at which germination of plum pollen occurred within 24 hours, the pollen tubes were very short, ranging from the shortest that could be measured to exceptional tubes that were 430 microns or .43 mm long.

TABLE I—EFFECT OF TEMPERATURE ON POLLEN TUBE GROWTH

Variety	Temperature (Degrees C)	Average Length of Pollen Tubes (Microns)		
		5-7-day-old pollen	10-day-old pollen	11-day-old pollen
Assiniboin.....	24	1,140±41		
	13	251±15		
	10	160±13		
De Soto.......	20–21	1,069±34	1,445±49	944±41
	13	660±59	554±27	349±20
	10	275±21	165±16	102±11
Rollingstone ..	20–21	729±46	1,280±55	*350
	13	350±24	353±23	190±13
	10	153±16	96±10	59± 4
Surprise.......	20–21		*780±30	*463±15
	13	423±51	281±19	179±15
	10	127±17	112± 5	46± 5
	13		*259±18	
	10		54± 9	
Wolf.........	20–21	1,596±53	1,439±44	*
	13	427±28	457±23	649±45
	10	193±15	153±16	155±18
Nicollet.......	20		865±41	*668
	13		247±16	*101
	10		136±9	

*Most or all pollen tubes burst within 24 hours.

At 13 degrees C, growth was much more rapid. Twenty tubes from 5-day-old Assiniboin pollen averaged 251 microns and ranged from 80 to 420, while Surprise, of the same age, averaged 423, with range from 40 to 1,130. Tubes from 6-day-old De Soto pollen averaged 660 microns with a range from 160 to 1,500. Seven-day-old pollen of Rollingstone produced tubes varying from 110 to 620 and averaging 350; in Wolf of the samé age the range was 170 to 640 and the average 427. Ten-day-old pollen of the sand cherry hybrid Nicollet produced tubes varying from 110 to 460 microns, averaging 247.

At room temperature long tubes were obtained in 24 hours. The longest tube produced by the pollen of Assiniboin grew 1,680 microns or 1.68 mm in 24 hours at 24 degrees C. The longest tube obtained from De Soto pollen grew 2.18 mm in 24 hours at 21 degrees C. The average at this temperature was 1.445 mm Rollingstone pollen incubated at 21 degrees C produced tubes averaging 1.28 mm, with one 2.23 mm long. All tubes of Surprise pollen burst in 24 hours at room temperature, the longest reaching 1.24 mm before bursting. In 24 hours at 20 degrees C the maximum growth with Wolf was 245 mm; with Nicollet, 1.30 mm.

Table II gives the average length of 20 pollen tubes from each culture of *Prunus serotina* incubated at temperatures from 5 to 40 degrees C inclusive. No pollen germinated at 0 degrees C, but there was considerable germination and very slow growth at 5 degrees C. At 40 degrees C, most of the pollen grains burst, usually before they had begun to germinate. The few tubes formed all burst while still very short, averaging 80 microns. At 36 degrees C

many of the grains swelled and burst without germinating and all the tubes burst while still shorter than the average length of pollen tubes grown at lower temperature down to and including 10 degrees C.

TABLE II—EFFECT OF TEMPERATURE ON POLLEN TUBE GROWTH OF *Prunus serotina*

Temperature (Degrees C)	Age of Pollen (Days)	Number of Tubes Measured	Average Length of Tubes (Microns)
40	¼	40	80
36	¼	60	355±14
32	5 and 6	40	598±12
28	5 and 6	40	682±12
24	¼	40	878±17
21	¼	20	1,242±18
20	¼	40	1,272±19
15	¼	40	1,072±18
15	5 and 6	40	672±14
10	¼	60	671±12
10	5 and 6	40	257±12
5	¼	20	85± 9
5	5 and 6	40	43± 2

In this study, 20 degrees C seems to be the optimum for *Prunus serotina,* as at higher temperatures the tubes burst before becoming as long as they did at 20 degrees C, and at lower temperatures they grew more slowly. It should be noted that if a shorter incubation period had been used, the best growth would probably have been made at a temperature higher than 20 degrees C.

Preliminary work with 5, 10 and 15 per cent sugar added to a 1 per cent agar gel indicated that at lower temperatures the lower sugar concentrations produce longer tubes than are formed on a 15 per cent sugar medium, but that at room temperature the tubes burst much sooner. If other concentrations of sugar-agar gel, or other types of media, had been used in these experiments, other optimum temperatures might have been found. Five and 6-day-old pollen produced tubes not quite as long as those from fresh pollen.

Relation of Age of Pollen to Germination and Pollen Tube Growth

The per cent of pollen germination was variable. In general, the per cent of viable pollen decreases as the age of the pollen increases. Twelve and 13-day-old pollen of the plums germinated very poorly, but no exact counts were made.

Age of pollen had its most noticeable effect on the appearance and vigor of the pollen tubes. Young pollen produced straight tubes which showed no tendency to burst, but were still growing at the end of 24 hours. From older pollen, the tubes were increasingly bent, particularly near the pollen grain. There was much more bursting, especially at room temperatures. All tubes from 10- and 11-day-old Surprise pollen, 11-day-old Wolf pollen, and 11-

day-old Rollingstone pollen, and half or more of the 11- and 12-day-old pollen of Nicollet burst when grown at room temperature. In some cases the tubes were still so short when they broke that the average length was as short or shorter than that from the same lot of pollen grown at 13 degrees C. Ten-day-old pollen of Rollingstone at 21 degrees C produced tubes averaging 1,280 microns, but a day later the tubes burst after reaching an average length of only 350 microns.

Even at the lower temperatures where bursting was not a factor, the rate of pollen tube growth was greatly retarded by senescence of pollen.

The Inheritance of Certain Characters in the Peach[1]

By J. S. Bailey and A. P. French, *Massachusetts State College, Amherst, Mass.*

A PEACH breeding project has been under way at the Massachusetts Agricultural Experiment Station for the past 10 years. The objects of this work are (1) to study the genetic composition of peaches and (2) to obtain new varieties better suited to Massachusetts conditions. This preliminary report concerns only the genetic studies.

Inheritance of albinism.—References in the literature to "albino" peaches are apparently all to the Summer Snow type which has lost all color except green. Among the seedlings of selfed Champion have appeared true albinos with no color whatever. Absence of chlorophyll makes this albino character lethal; seedlings grow 3 or 4 inches and die. In a total of 209 selfed Champion seedlings, 50 were of this albino lethal type. When this population is tested on a 3:1 ratio by the probable error method the value obtained for $\frac{D}{P.E.}$ is 0.53, showing that the small deviation from expectancy is well within the limits of random sampling. Hence, this albino lethal character is undoubtedly a simple Mendelian recessive.

Inheritance of foliar glands.—Since the manner of inheritance of foliar glands has already been reported by Connors(1) the data in Table I are given as further evidence supporting his conclusions that the reniform type is dominant, eglandular is recessive, and globose is intermediate.

In the crosses of reniform (RR) by globose (Rr) the ratio obtained is approximately 1:1, as would be expected if these gland types are controlled by one pair of genes. In the reciprocal crosses globose (Rr) by eglandular (rr) and eglandular (rr) by globose (Rr) the ratio is exactly 1:1. The progeny of the selfed globose (Rr) type do not conform closely to a 1:2:1 ratio, yet, the data tend in that direction and show that globose is intermediate. Eglandular (rr) selfed gave all eglandular seedlings as was expected.

The correlation of crenate leaf margins with reniform or globose glands, and of serrate margins with the eglandular condition has been observed by several workers. However, in one lot of seedlings several individuals have appeared with very wavy leaves, globose glands, and very sharply serrate margins. No data available explain this new combination of characters.

Inheritance of toughness of flesh.—Among the seedlings of selfed Belle and selfed Champion have appeared a number with fruits having tough or non-melting flesh, such as is possessed by the clingstone

[1]Contribution No. 161 of the Massachusetts Agricultural Experiment Station.

peaches commonly used by canneries. Among the selfed Belle seedlings there are 220 individuals with melting and 73 with non-melting flesh, and among the selfed Champion seedlings there are 70 melting and 23 non-melting. The appearance of this non-melting flesh character was reported by Connors (2) as "obviously a recessive." On the basis of a 3:1 ratio the value of $\frac{D}{P.E.}$ for the Belle progeny is 0.05 and for the Champion progeny 0.27. Since the slight deviations from a 3:1 ratio are clearly due to random sampling, it is very probable that melting flesh is dominant.

TABLE I—INHERITANCE OF GLAND TYPE

Parentage	Type	Progeny		
		Ren.	Glob.	Egland.
Gold Drop x Early Crawford....	R x G	6	7	0
Hale x Early Crawford.	R x G	14	18	0
Total..........................		20	25	0
Selfed Early Crawford	G	3	3	1
Selfed Fitzgerald..	G	30	46	18
Selfed Champion..........	G	28	49	27
Selfed Seedling S-K 29.	G	3	5	3
Total..		64	103	49
Seedlings				
S-K 29 x S-K 31..................	G x E	0	11	9
S-K 31 x S-K 29.......	E x G	0	4	6
Total..........................		0	15	15
Selfed Seedling S-K 31...............	E'	0	0	15

Inheritance of stone adhesion.—The data for selfed Elberta in Table II agree very closely with Connors' (2) data and show that free is dominant over cling in that variety. When calculated by the probable error method, the value of $\frac{D}{P.E.}$ equals 0.62 for a 3:1 ratio. In this calculation the cling non-melting individuals have been included with the cling melting group, although, as will be shown later, they may be genotypically free. If these cling non-melting individuals belong in the free class, then the goodness of fit would be almost perfect for a 3:1 ratio.

However, in classifying peaches as free or clingstone, there is usually a group of semi-cling individuals. After several years' observation most of these can be classified with either the frees or the clings, since they usually vary from semi-cling to free or from semi-cling to cling. In the data presented in Table II classification has been made on this basis. Only those individuals which were always semi-cling have been classified by themselves. However, in the calculation of percentages these few semi-cling indi-

viduals have been grouped either with the cling or the free class. In the selfed Belle, the three semi-cling individuals have been grouped with the frees because out of 32 semi-cling individuals which could be classified definitely only two belonged with the clings. Similarly in the selfed Champion, two semi-clings have been classed with the clings and five with the frees because out of 20 semi-cling individuals 14 gave evidence of belonging with the frees and six with the clings. Furthermore, regardless of how these few semi-clings are classified, the final conclusions are not materially affected.

TABLE II—INHERITANCE OF STONE ADHESION AND FLESH TOUGHNESS

	Free Melting	Cling Melting	Semi-cling Melting	Cling Non-melting	Total
Selfed Elberta					
Number	72	25	0	2	99
Per cent	72.7	25.2		2.1	100
Selfed Belle					
Number	205	12	3	73	293
Per cent	71	4.1		24.9	100
Selfed Champion					
Number	49	14	7	23	93
Per cent	58.1	17.2		24.7	100

Linkage between stone adhesion and toughness of flesh.—If freestone is dominant over clingstone, as indicated by the selfed Elberta data, and melting flesh is dominant over non-melting flesh, as indicated by the data for selfed Belle and selfed Champion, a 9:3:3:1 ratio would be expected when a variety heterozygous for these two pairs of characters is selfed, provided they are independent of each other; that is, there would result 9 free melting, 3 cling melting, 3 free non-melting, 1 cling non-melting.. The data for selfed Belle in Tables II and III show: (1) no free non-melting individuals have appeared, and (2) the data do not conform to a dihybrid ratio for independent assortment.

Absence of free non-melting individuals indicates that some other factor causes all of the non-melting individuals to be phenotypically clingstone, although some should be genotypically free. This assumption would require a 9:3:4 ratio with the non-melting class constituting 25 per cent of the population. Table II shows that the non-melting class of selfed Belle and of selfed Champion each approximates 25 per cent.

The deviation of the Belle data from a 9:3:4 ratio is too great to be due to random sampling, since the goodness of fit calculated by the X^2 method gives a value for X^2 of 44.88, several times greater than the value necessary for a significant deviation. Furthermore, when calculated by the probable error method, as in Table III, the value of $\frac{D}{P.E.}$ equals 7.54 for a 9:7 ratio and 9.52 for a 13:3 ratio. Both of these values also indicate a deviation from expectancy too great to be due to random sampling.

TABLE III—STATISTICAL ANALYSIS OF SELFED BELLE DATA

	Free Melting	Cling Melting	Cling Non-melting
Observed	208	12	73
Expected 9:3:4	164.81	54.94	73.25
Deviation	43.19	—42.94	—0.25
P. E.	5.73	4.51	5.00
Deviation / P. E.	7.54	9.52	0.05

On the basis of the data in Table III the hypothesis is presented that there is linkage between the free-cling characters and the melting-non-melting characters in the Belle variety, and that the genes are in the coupling phase. In this case the cling melting offspring and the genotypically free non-melting individuals mentioned above are cross-overs. As only the cling melting cross-overs can be observed and counted these individuals constitute but one-half of the total number of cross-overs. The data in Table III indicate about 8 per cent crossing over. Calculated for 8 per cent crossing over the value of X^2 is 0.06. With 293 individuals the probable error of 8 per cent crossing over is ± .011. The fit calculated by each of these methods is extremely good.

The selfed Champion data in Table II present a different situation. These data fit a 9:3:4 ratio, since the value of X^2 is 0.18. Therefore, it is possible that the free-cling and the melting-non-melting characters are inherited independently in this variety. If they are, then either stone adhesion or toughness of flesh must be controlled by a different set of genes in this variety than in Belle. However, 93 is too small a population to distinguish 8 per cent crossing over from independent assortment if the genes are in the repulsion phase. Calculating by the X^2 method, it would take approximately 300 individuals to make this distinction.

The appearance of 2 per cent of non-melting progeny among the selfed Elberta seedlings, which agrees with Connors' (2) data, cannot be explained on the basis of 8 per cent crossing over as in Belle or on the basis of independent assortment. It would be possible to explain their appearance by the assumption that toughness of flesh is controlled by more than one pair of genes. Then the genes controlling stone adhesion would be linked to one of these pairs of genes controlling toughness of flesh. At present the data available are insufficient to support this assumption.

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The J. H. Hale Peach as a Parent in Peach Crosses

By M. A. Blake, *N. J. Agricultural Experiment Station, New Brunswick, N. J.*

THE J. H. Hale peach was found as a chance seedling in an orchard by J. H. Hale, South Glastonbury, Connecticut, and was distributed in 1912 by the William P. Stark Nurseries. It is apparent that the variety is very closely related to Elberta. The tree is very similar to Elberta in habit of growth, except that it is smaller.

The New Jersey Station has grown and fruited a large number of peach seedlings obtained as a result of selfing Elberta. A number of these were semi-dwarf, and some possessed fruit characters resembling those of J. H. Hale. The Station has upon its grounds a fully dwarf type of Elberta, which appeared among the seedlings from a dwarf bud sport of Elberta, the progeny of which contained also some intermediate tree forms.

The leaves of J. H. Hale are practically identical with Elberta, and the flower type is similar except that it is pollen sterile. The variety behaves similarly to Elberta in other ways which definitely indicate its close relationship to that variety.

Characters of J. H. Hale

The J. H. Hale peach makes a strong appeal to peach growers because of its fruit characters. The most outstanding of these may be listed as follows: (1) Form round, (2) size large, (3) pubescence short and light, (4) skin thick and tough, (5) skin color yellow and attractive red, (6) apex of fruit roundish, (7) suture very shallow, (8) flesh color orange-yellow with considerable red at pit, (9) flesh very firm and fine grained, (10) adhesion free from pit, and (11) edible quality good.

The tree characters of the J. H. Hale do not compare favorably with its fruit characters. Its slightly dwarf habit is not a serious objection although the trees do not attain a size sufficient to produce large yields as quickly as Carman or Belle, for example. One marked weakness, however, is its susceptibility to winter injury to the trunk and roots and to collar rot near the surface of the soil. A second important weakness is that it is not nearly so adaptable to variations in growing environment as Elberta. A third weakness is that the flowers are pollen-sterile and the tree as a whole is only medium hardy. The leaves and fruit are also very susceptible to bacterial leaf spot and the edible quality of the fruit becomes too acid under some conditions. Practical peach growers recognize the possibilities, however, of a peach that would possess the fruit characters of J. H. Hale, but have fertile flowers and a more adaptable and hardier tree. The fruit characters of the J. H. Hale peach,

therefore, made it appear promising for breeding work at the New Jersey Station.

Beginning of Breeding Work

Some preliminary work in peach breeding was done in New Jersey just previous to 1914 but was not undertaken upon an extensive basis until April, 1914. Several entire trees at the Vineland Expermental Orchard were then covered with cheese cloth tents and a considerable volume of pits obtained from crosses that season. From 1914 to 1928, inclusive, 131 different crosses were made in which 77 different varieties and species were employed.

J. H. Hale crosses.—In 1921 Connors first began to make crosses with the J. H. Hale and in 1922 reported (1) the variety as pollen sterile. From 1923 to 1928, inclusive, Connors made 42 crosses with J. H. Hale. Nine were with common named varieties; six with varietal types introduced by the Foreign Seed and Plant Introduction Bureau at Washington; three with variations of *Prunus (Amygdalus) kansuensis*, also obtained from the Foreign Seed and Plant Introduction Bureau; 23 with New Jersey Station seedlings; and one with the hard-shelled almond. Pollen from the 38 different varieties, the two distinct species and the two variations of the same, all fertilized J. H. Hale successfully.

Beginning in 1919, Connors made reports from time to time as to the inheritance of peach characters and summarized his observations in 1928 (2). In 1926 Dr. Connors was made head of a new department of Ornamental Horticulture and since that time the detailed notes upon the behavior of the progeny obtained from peach crosses have been taken by the Chief in Horticulture.

Previous to 1929 (3) Connors had reported that small size of fruit was dominant over large, that white flesh color was dominant over yellow, that melting flesh was dominant over what he described as tough, and that large blossom size was dominant over small. He stated that reniform glands were dominant over eglandular, and also reported observations as to flesh adhesion, ripening dates, and pollen sterility. He found that in some crosses of J. H. Hale with fertile-flowered varieties the progeny was 100 per cent fertile while in other crosses 50 per cent of the progeny was pollen sterile so that he concluded that pollen sterility was recessive.

Observations Since 1928

In 1925, a cross was made of Hale x Chili, which is very distinct in tree, foliage, and fruit characters from the female parent. The tree appears somewhat lacking in vigor, with slender twigs and small leaves, but is of outstanding hardiness. The fruit is small to medium in size, oblong-conic, and heavily pubescent. The flesh is yellow and rather dry. The progeny of this cross so closely resembles Chili in every way that it is impossible to distinguish many of them from the pollen parent. In other words, the collection of

characters termed "J. H. Hale" was, as a group or a variety, recessive to the collection of characters termed "Chili," except as to red color of flesh about the pit which is common to both parents.

J. H. Hale x Iron Mountain.—The Iron Mountain is a large oblong-oval, white-fleshed peach ripening a little later than J. H. Hale. It has very little red outside color, is heavily pubescent, the flesh is white to the pit, and the tree has a distinctly vigorous, upright habit. In other words, it possesses many characters which distinguish it from J. H. Hale.

The progeny of the first generation all very closely resemble Iron Mountain in tree habit, form of fruit, and color of flesh. The influence of J. H. Hale was shown by a tendency to redness of flesh about the pit and to a slightly more acid flavor in some seedlings, and the flowers of the progeny are of the large-medium type as compared to the small type of Iron Mountain. There was slightly more red on the skin of some of the progeny than is the case with Iron Mountain, but the brilliant red color, the short pubescence, the round form, and the outstanding characters that make up J. H. Hale do not appear in the first generation cross with Iron Mountain.

J. H. Hale x Chinese Blood.—The Chinese Blood, S. P. I. No. 36717, was obtained from the United States Department of Agriculture. The fruit is very large, oval-conic in form, and of a characteristic dull purplish-red color, with a greenish under-color. The flesh is blood red and decidedly acid. The tree is distinct in habit; wide spreading, with large, broad, flat leaves. A considerable number of seedlings from this cross fruited in 1932. Many of them are very similar to the pollen parent. J. H. Hale apparently did not modify to any appreciable extent the type which is Chinese Blood. The flesh of a percentage of the progeny which ripen late is only slightly blood red and only mildly acid. The writer feels confident, however, that this same variation would be obtained in progeny secured as a result of the self-pollination of Chinese Blood, if it were possible to secure such a progeny.

J. H. Hale x Japan Dwarf Blood.—A cross was made between J. H. Hale and another blood-fleshed peach, Japan Dwarf Blood, in 1926 and in 1927. The fruit is small, regular, and round with a distinctly pointed apex. The progeny of the first generation all closely resemble Japan Dwarf Blood except that the trees, as a rule, are somewhat less compact in habit. The flesh of the late ripening individuals was less red and less acid as was the case in the Chinese Blood cross. It is possible that these two blood peaches may be quite closely related.

J. H. Hale x S. P. I. 55564 (Non-melting).—S. P. I. No. 55564 is a peach introduced from Spain by the United States Department of Agriculture. The fruit is small with very little red skin color. The flesh is yellow and of the non-melting clingstone type desired by canners. The tree is a rather vigorous upright grower and quite distinct from J. H. Hale. The progeny of this cross fruited

in 1932. All of the trees produced small fruits as might be expected and all were of the melting flesh type. It was learned at the New Jersey Station in 1930 (4) that the significant difference between melting and non-melting types of peaches occur in the final stages of ripening and is associated chiefly with the retention of a high content of insoluble proto-pectin in the cell walls of the flesh. Under the term "tough", Connors suggested in 1928 that this character was recessive. His observations are supported in the cross just described.

J. H. Hale x Amarillo Tardio.—Another cross of J. H. Hale by a seedling of Amarillo Tardio, a Spanish peach of the non-melting canner type listed as S. P. I. No. 55536, gave results similar to those reported for S. P. I. No. 55564.

Three Types of Flesh Firmness.—The flesh of ripe peaches can be divided into at least three classes, namely, soft-melting or watery, firm-melting, and non-melting. The flesh of some varieties which is non-melting at the shipping stage finally becomes melting. The progeny of the cross of J. H. Hale with the non-melting S. P. I. No. 55564 all possessed flesh of the soft-melting, watery type. In other words, both the non-melting flesh of the pollen parent and the firm melting flesh of the J. H. Hale were dominated by flesh of watery melting character. The pubescence on the fruits of the progeny resembled that of the pollen parent. The skin of the fruits was slightly more red than that of the pollen parent but was in no way comparable to that of the J. H. Hale. In other words, the collection of characters termed "J. H. Hale" was again almost completely recessive to the collection designated as "S. P. I. No. 55564."

J. H. Hale x Prunus (Amygdalus) kansuensis.—*Amygdalus kansuensis*, also termed the "Bush Peach of China," was introduced in 1914. S. P. I. No. 39428 is a pink flowered form secured by F. N. Meyer from the mountains south of Sianfu, China, while S. P. I. No. 40001 is a white flowered form. F. N. Meyer purchased the seeds of the latter on the streets of Sianfu, Shensi. The tree has a very distinct bushy and willowy habit of growth and is also characterized by the development of numerous, strong, upright sucker growths from the base. The bark of the base of these sucker shoots is a light gray and entirely distinct from such shoots upon *A. persica*. The leaves are narrow and sharp pointed, the fruit buds are small, pointed, and very numerous. Formation of 30 or more buds per foot of annual growth is common. The flowers are readily distinguished from *A. persica* and open about 10 days before J. H. Hale at New Brunswick, N. J. The fruit is small and round wth a short but harsh feeling pubescence. The flesh is white, red about the pit, and very acid and astringent. Crosses were made with J. H. Hale in 1925 and a number of trees obtained. All of the progeny greatly resemble *A. kansuensis* in tree, foliage, and fruit characters. The flowers of the hybrids are more like *A. persica* than are those of the pollen parent. The time of blooming is a bit

later and the fruits are slightly larger, but no trace of the typical J. H. Hale can be noted. Not a single pollen-sterile tree was found among the progeny.

J. H. Hale a Recessive Type.—Evidence from many other crosses could be given but more is hardly necessary to prove the fact that the variety J. H. Hale is largely a combination of recessive characters that are almost completely dominated by other collections of characters termed "varieties," such as Chili, Iron Mountain, Chinese Blood, and others.

J. H. Hale Closely Related to Elberta.—The parentage of J. H. Hale is unknown, but is reported as a chance seedling found growing in a commercial orchard by J. H. Hale. Elberta pits are sometimes used by nurserymen to furnish stocks for budding and a seedling with the foliage characters of J. H. Hale might have developed in the nursery row and have been considered a budded tree of Elberta.

There is a considerable volume of evidence to support the theory that J. H. Hale is largely a recessive variation of Elberta. The progeny of Elberta self-pollinated at New Brunswick, N. J., included a number of individuals that were semi-dwarf in habit like J. H. Hale and possessed fruit characters somewhat similar to J. H. Hale. A fruit grower at Vineland, N. J., raised from an Elberta pit a tree that proved almost identical with J. H. Hale. The New Jersey Station has a full dwarf sport of Elberta and several that are intermediate in dwarfness.

J. H. Hale x Paragon.—In 1921, the New Jersey Station secured from the Office of Foreign Seed and Plant Introduction in Washington, a peach named Paragon which was obtained from Mr. H. R. Wright of New Zealand. When this variety came into bearing about 1924, it attracted the interest of the author. The tree was a semi-dwarf and produced large fruits of high color which resembled Hale in firmness and in type of pubescence. The flesh was yellow and a firm-melting cling. Though rather easily distinguished from J. H. Hale it resembled that variety in many ways. The flowers of Paragon are of the medium type and self-fertile. When this variety was selfed, it produced seedlings of a semi-dwarf spreading growth habit with narrow leaves which were remarkably alike and many produced pollen-sterile flowers.

In 1927, J. H. Hale was crossed with the New Zealand "Paragon." In the summer of 1932 the progeny from this cross fruited. A large percentage of them produced fruits that are large and firm-fleshed. The pubescence is short and thin and the skin is attractively colored much like that of J. H. Hale. Correspondence between the writer and Mr. Wright several years ago revealed the fact that Paragon was an Elberta seedling which Mr. Wright had himself selected. This appears to be further evidence that J. H. Hale is largely a combination of recessive characters, probably largely inherited from Elberta.

Relationships of Characters

The discussion of the behavior of J. H. Hale as a parent in breeding work has brought forth the inheritance of certain characters that have not been mentioned by Connors: (1) Red flesh color about the pit is apparently dominant over absence of red at the pit; (2) watery-melting flesh texture is apparently dominant over firm-melting flesh texture; (3) non-melting flesh is recessive to both watery-melting and firm-melting flesh texture; (4) blood red flesh was dominant over the absence of red in the crosses made at New Brunswick; (5) heavy pubescence is apparently dominant over short or light pubescence. (In crosses of peaches with nectarines at the New Jersey Station pubescence has been dominant); (6) oval-conic, oval-oblong, and round but pointed forms in Chili, Iron Mountain, Chinese Blood, Japan Dwarf Blood, and others were dominant over round; (7) full-dwarf and semi-dwarf growth habit have been recessive to standard tree size in the J. H. Hale crosses at New Brunswick; (8) early blooming as characterized by *Amygdalus kansuensis* was dominant over late blooming by J. H. Hale; (9) vigorous sucker development from the trunk and main branches as characterized by *A. kansuensis* was dominant over slight sucker development as shown by J. H. Hale.

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Results Obtained from Crosses Between Danugue (Gros Guillaume) and Ontario and Hubbard Grape Varieties

By Richard Wellington, *Experiment Station, Geneva, N. Y.*

THIS paper recounts work with two crosses as illustrative of a phase of the grape breeding work at the New York Agricultural Experiment Station. Other combinations, just as important, have been made, but space does not warrant detailed discussion.

In 1925 the large, firm-fleshed, black-fruited Danugue or Gros Guillaume attracted attention as of probable value for breeding purposes. The following year two varieties, namely, Ontario, a very early white grape, and Hubbard, a large black grape ripening about 2 weeks later than Ontario, were used as the hardy parents. Ontario was originated at the New York Agricultural Experiment Station by crossing Winchell with Diamond. Its vinous-flavored fruit and intermittent tendrils indicate that it is not a pure *Vitis labrusca* but a hybrid between *V. labrusca* and *V. vinifera.* Hubbard, produced by the late Joseph Bachman of Arkansas by crossing Brighton with Campbell, is likewise a hybrid, for Brighton is at least half *V. vinifera.* One hundred and eighty-six seeds were obtained in 1926 from the cross Hubbard by Gros Guillaume, and 368 from the cross Ontario by Gros Guillaume. From the former cross 131 seedlings were raised in 1927 and set out in the nursery. In 1928 only 25 strong and 3 weak plants remained, and 3 of the 25 strong plants set in the vineyard succumbed before fruiting. In other words, about 83 per cent of the seedlings died, probably from winter injury. Only 37 seedlings of the Ontario cross fruited, the mortality being within 1 per cent of the Hubbard cross.

A higher proportion of the Hubbard by Gros Guillaume seedlings died in the nursery but fewer in the vineyard. However, time and place of death makes little difference in the final results. Possibly the variation in time of death was due to a slightly better protection or location in the nursery.

Judging from the vine and fruit characters of the seedlings planted in the vineyard, all possessed hybrid characteristics. Continuous tendrils appeared on four vines of Ontario by Gros Guillaume but all the others with the exception of three irregulars in Hubbard by Gros Guillaume had intermittent tendrils. Lobing of the foliage varied from five to three, and the tomentum on the lower surface varied from medium to light with frequent hairiness on veins. All of the Hubbard by Gros Guillaume seedlings bore upright stamens, while three out of 35 seedlings of Ontario by Gros Guillaume bore reflexed stamens.

In season of ripening, the seedlings were distributed between the parents, the mean of Ontario by Gros Guillaume being approximately 1 week earlier than that of the Hubbard cross. This dis-

tribution is according to expectations for, as already stated, Hubbard averages about 2 weeks later than Ontario.

The clusters of fruit and size of berries averaged slightly larger in the Hubbard cross, and this again should be expected since the cluster and berry of Hubbard averages larger than that of Ontario. Only one of the 22 Hubbard seedlings had no oval or roundish oval berries, while four out of 37 of the Ontario seedlings lacked an oval tendency. In fruit color both crosses were very similar, even though Hubbard is black and Ontario is white; 19 of the Hubbard being black, one reddish black, and two dark red, while 32 of the Ontario were black, four reddish black, and one dark red. Apparently Gros Guillaume does not carry a factor for yellow fruit color. The meatiness of the vinifera was noted in over half the population in each cross and the vinous quality in over three-fourths. In quality, as also might be expected, the Ontario seedlings average higher. Only one seedling of Hubbard was rated very good, while eight of the Ontario fell in this class. The good class contained 17 and 18 respectively, the fair four and eight, and the poor none and two.

In selection for future propagation, both lots of seedlings were remarkably similar, approximately 41 per cent of the Hubbard and 43 per cent of the Ontario being saved. A number of the Hubbard seedlings were selected because of their remarkably fine large clusters and their large, firm berries, while many of the Ontario seedlings were saved for their high quality and appearance. Undoubtedly many of the "saved" seedlings will be dropped in second and third tests for one reason or another, but a few of them ought to survive the more rigid and extensive trials.

The improvement of grape varieties in the East is undoubtedly dependent upon the hybridizing of our grapes with the viniferas. The two crosses just noted indicate strongly that such a method of attack is most promising and feasible. Already a number of vinifera varieties have been selected as prospective parents on account of one character or another, and if nothing unforeseen interferes with the program of grape breeding work, they will be used extensively in the future.

Apple Breeding: A Study on Seedling Fruits Produced by Longfield[1]

By H. L. LANTZ, *Iowa State College, Ames, Ia.*

FOUR progenies of Longfield are reported upon here to indicate the nature and amount of variation found in size, form, and color of the fruits, and of the flesh characteristics as to color, texture, juice, flavor, quality, and season.

Longfield is a hardy, productive apple of Russian origin. Its fruit is small, pale clear yellow, sometimes red blushed, and of roundish, symmetrical form. The flesh is white, very tender, fine grained, juicy, sprightly subacid, good quality, and ripens in late August or early September at Ames. It was used for crossing by Prof. S. A. Beach in 1906–07 and four progenies were produced: Longfield x Gano (125 fruited), McIntosh x Longfield (61 fruited), Longfield x Mt. Beet (27 fruited), and Ben Davis x Longfield (13 fruited).

The trees produced by each of the four crosses were generally productive and satisfactorily vigorous. The trees of McIntosh x Longfield averaged superior to those produced by the other crosses. When these progenies were compared with many others in the seedling orchards, it was evident that productivity was transmitted by Longfield.

Data on seedling fruit size, form, color, and flesh characteristics are presented in terms of percentage, to show comparisons between progenies. It is doubtful whether genetic interpretations are possible, but the data present a fairly good picture of these progenies and certain conclusions seem warranted with respect to the relative breeding values of Gano, McIntosh, Mt. Beet, and Ben Davis when crossed with Longfield. Of the four progenies, only McIntosh x Longfield produced seedlings worthy of naming.

INHERITANCE OF SIZE, FORM, COLOR AND FLESH CHARACTERISTICS

Size. The data show the superiority of McIntosh over the other varieties when crossed with Longfield in transmitting desirable fruit size to its progeny; 68.9 per cent of the fruits of the McIntosh progeny rated medium, above medium, and large; those of Gano, 45.6 per cent; and those of Mt. Beet, 25.9 per cent. It may be noted in passing that of the Gano progeny, five produced fruits larger than either parent; and of the McIntosh progeny, five produced fruit much larger than either parent. The Mt. Beet apple is below medium size, red, and subacid. Seventy-five per cent of the fruits produced by this cross were below medium and small. The conclusion is therefore tentatively drawn that the phenotype of size is transmitted to the progeny. It is obvious that Longfield

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TABLE I—DISTRIBUTION OF FRUIT CHARACTERISTICS AMONG APPLE SEEDLINGS FROM FOUR PROGENIES OF LONGFIELD

Cross	Number Fruited	Size					Form						
		Large	Above Med.	Med.	Below Med.	Small	Res.* Long	Res.* Gano	L. Base G. Apex	Res.* McIn.	Res.* B. D.	Oblate	Oblong
L. x G.	125	4	16	25.6	39.2	15.2	28.0	25.6	12.0			19.2	15.2
M. x L.	61	8.2	23	37.7	26.2	4.9	23.0			46.0		29.5	1.5
L. x Mt.	27	0	3.7	22.2	55.5	18.6	66.6					11.1	22.2
B. D. x L.	13	0	7.7	30.8	61.5	0	15.8		30.8		30.8	7.7	15.8

Cross	Number Fruited	Color										Flesh	
		Longfield	Gano	McIntosh	Mt. Beet	Ben Davis	¼ Blushed	¾ Blushed	Red Striped	Green Bronze Blush	Green	White	Yellow
L. x G.	125	26.4	28.8				14.4	12.0	18.4			59.2	40.8
M. x L.	61	31.2		14.8					39.3	11.5	3.2	67.3	32.7
L. x Mt.	27	40.8			50.8		7.4					85.2	14.8
B. D. x L.	13	30.8				46.2			23.0			53.8	46.2

Cross	Number Fruited	Firmness			Texture			Grain			Juice		
		Firm	Med.	Soft	Tender	Med.	Tough	Fine	Med.	Coarse	Juicy	Med.	Dry
L. x G.	125	64.7	35.3	0	46.4	36.8	16.8	16.8	47.2	36.0	39.2	52.0	8.8
M. x L.	61	42.7	54.1	3.2	65.6	32.8	1.6	29.5	54.2	16.3	60.7	36.1	3.2
L. x Mt.	27	40.7	59.3	0	44.5	48.2	7.3	18.5	55.5	26.0	40.7	40.7	18.5
B. D. x L.	13	53.8	46.2	0	61.5	38.5	0	23.1	46.2	30.7	46.2	53.8	0

Cross	Number Fruited	Flavor				Quality				Season				
		Sweet	Mild	Sprightly	Sour	V. Good	Good	Fair	Poor	Aug.	Sept. Oct.	Nov. Dec.	Jan. March	March later
L. x G.	125	4.0	64.7	31.3	0	2.4	28.8	53.6	15.2	3.2	16.8	49.6	28.0	2.4
M. x L.	61	8.2	52.5	37.7	1.6	14.8	39.3	37.7	8.2	16.3	45.9	26.3	11.5	0
L. x Mt.	27	0	81.5	18.5	0	0	14.8	55.5	29.7	48.2	44.4	7.4	0	0
B. D. x L.	13	0	46.2	46.2	7.6	0	15.4	61.5	23.1	0	15.4	61.5	23.1	0

*Indicates resemblance to parent variety.
L. = Longfield G. = Gano M. = McIntosh Mt. = Mt. Beet B.D. = Ben Davis

carries factors which produce desirable fruit size but that large-fruited varieties should be crossed with it to produce satisfactory proportions of commercial fruit sizes.

Form. Form has less significance horticulturally than size, although the oblong forms are generally preferred to the oblate in the commercial world. Form inheritance is a difficult study because distinct classes of form are not easily determined and it is difficult to classify satisfactorily the numerous slight variations. The primary forms, namely, conic, roundish, oblate, and oblong appear in most progenies, but the proportion of each form in different progenies is far from constant. It has been convenient in these studies to classify the seedling forms first as to parental resemblance and second to non-parental form types. In the progeny from the Longfield (roundish) x Gano (conic) cross, approximately 25 per cent closely resembled Longfield in form, and 25 per cent resembled Gano; 19 per cent were oblate, 16 per cent were oblong, and 12 per cent were intermediate, with Longfield base and Gano apex. In the cross of McIntosh (roundish oblate conic) x Longfield (roundish) approximately 23 per cent of the seedling fruits resembled Longfield in form, 46 per cent the McIntosh, 30 per cent were distinctly oblate, and only 1.5 per cent were *oblong.* In the Longfield (roundish) x Mt. Beet (roundish) cross, 66.6 per cent of the seedling fruits were round like the parents, 22 per cent were oblong, and 11 per cent were oblate. Form is doubtless transmitted on a complex multiple factor basis. These percentages indicate that each of the varieties carries factors for roundish, conic, and oblate forms, that all except McIntosh carry factors for oblong, but that these factors are not transmitted in equal proportions to all the progenies.

Color. Color studies with apple progenies produce data which is difficult to interpret satisfactorily. In these crosses red is dominant over yellow, striping and mottling are dominant as a pattern over solid red, but the proportions of the color types in these progenies vary considerably. The Longfield (pale yellow, thin red blush) x Gano (nearly self red) cross produced apples of which 26 per cent resembled Longfield, 28 per cent Gano, and 46 per cent were either 1/3 blushed, 2/3 blushed, or striped with red. In the McIntosh nearly solid self red) x Longfield (pale yellow, thin red blush) cross, 31 per cent of the fruits resembled Longfield, 15 per cent the McIntosh, 39 per cent were red striped, 12 per cent were green with bronze blush, and 3 per cent were green. A considerable number of the red striped seedling fruits distinctly resembled the Fameuse in tone and pattern of color, which fact helps confirm the belief that there is a relationship between the McIntosh and the Fameuse. In the Longfield (pale yellow, thin red blush) x Mt. Beet (solid deep red, obscure striping) cross, the parental color types dominated the seedling fruits and only 7 per cent of blushed fruits of non-parental color appeared. Evidently Mt. Beet is more nearly pure for red color *pattern* than are the other parents used in these crosses. From these data it seems that Gano carries factors for red but not for

yellow, as evidenced by the fact that all of the Longfield-colored type fruits invariably carried a pale red blush. Of particular interest was the appearance of a number of fruits in the Gano cross which were far more attractively colored than either of the parents. Nearly 75 per cent of the fruits of the Gano progeny carried red, while in the McIntosh progeny 46 per cent were either of Longfield color or greenish with but little red color. The other 54 per cent carried red. The reds in the Gano cross segregated into four color types, and in the McIntosh cross two red color types appeared, namely solid reds and the striped and mottled reds. Color type or pattern and the amount of surface covered by any given color are apparently due to a complex factor situation, but without doubt the parent varieties differ considerably in such complexity.

Flesh characteristics. An examination of the table shows the distribution of the variations in color, firmness, texture, grain, juice, flavor, quality, and season of the fruits produced in each of the four progenies. Each parent apparently carries factors for both yellow and white flesh and a complex set of factors for each of the other flesh characteristics. Our chief interest in these data which concern flesh characteristics is to call attention to the fact that the percentage of seedling fruits of desirable texture, grain, juice, and quality was considerably higher in McIntosh than in the Gano progeny. The difference in quality is particularly noticeable. The flesh characteristics of both Gano and of Longfield were recovered in a number of seedlings. High quality was not found among the seedlings of the Longfield x Gano cross, although a number of these fruits were easily the equal of Gano. In the McIntosh x Longfield cross, however, a comparatively high percentage of the seedling fruits rated very good and good in quality.

The season of the fruits of Gano seedlings averaged considerably later than did the season of the McIntosh seedlings. Season of ripening undoubtedly is regulated by a complex factor situation. In all progenies studied where there were 30 or more seedlings, the seedlings ranged in season from early to late but the proportion which ripened at the different seasons is determined by the phenotypic characteristics of the parent varieties used in the crosses.

Practical Results

These progenies of Longfield demonstrate that though the seedling fruits vary greatly in size, color, flesh, quality, and season, they tend to follow the characteristics of their parents with respect to the relative numbers which possess the different characteristics such as size, form, color, quality, and season.

Gano in this cross produced no fruits worth naming; although several were of commanding appearance, in no case was high quality found. In the McIntosh progeny two seedling fruits were named. The Maud is an excellent white-fleshed eating apple which ripens in early September as grown at Ames. It is full red when

well colored and about medium size. The tree is productive and hardy. Sharon is regarded as one of the most promising apples originated at Ames. The tree is hardy, productive, and the fruit hangs until mature, which McIntosh fails to do during most seasons in Iowa. The fruit is medium in size, bright red striped over yellow, and the flesh is tender, firm, juicy, mild, rich, and aromatic in flavor, very good in quality and is prime for dessert through January in good storage. These varieties, Maud and Sharon, are most promising for planting in the central and northern half of Iowa and in similar climates where good winter apples are not successfully grown.

The seedling fruits of the Longfield x Mt. Beet cross produced show a much narrower range in the variation of size, color, form, quality, and season. None was large, all were of medium quality, and on the early side of mid-winter in season.

Present Status of Mutation Studies in Deciduous Fruit Varieties

By J. T. Bregger, *Cornell University, Ithaca, N. Y.*

PRACTICAL and even scientific horticulturists almost without exception have until recently held the opinion that somatic mutation offers no great chance of economic improvement of our deciduous fruits. Within the past few years, however, this attitude has been changing rapidly, mainly as evidence has been piling up, not only on the existence of so many of these mutations, but in their actual propagation and planting running into millions of trees, until there are now actually a few horticulturists and geneticists who believe that the *greatest* opportunity for improving our deciduous fruit variety clones lies in this largely unexplored field of bud mutation and bud selection.

The history of the origin of new varieties or strains of fruits and other cultivated plants as bud mutations has been previously reviewed by Shamel (21) and summarized by the author (3) (4), so that repetition is not necessary. A variety list of such plants, exclusive of our deciduous fruits, will show a surprising number of those having mutation origins, particularly among the Roses, Chrysanthemums, Carnations, etc. According to Asseyeva (1) and others, bud mutations are of frequent occurrence in the potato, a common example being the main commercial variety of the Northwest, the Netted Gem or Russet Burbank. The main variety of orange in California (Navel) is of bud sport origin, and somatic mutation of great diversity are to be found in other commercial citrus varieties.

Several important varieties of our deciduous fruits outside of the apple have orginated as bud mutations. These include the Coates No. 1418 prune, the seedless Corinth grape, and two color mutations reported in both plum (6) (13) and grapes (28). Up to 1921, not many mutations had been reported in the apple, although a few were known and being propagated, including red variety strains of Gravenstein, Rome Beauty, Twenty Ounce, Ben Davis, and Williams. It might be mentioned here that horticulturists are still not in perfect agreement regarding the true origin of Black Ben and Gano. The author, however, prefers to include these two "varieties" in the bud sport class, rather than to call them seedlings, on the basis of their apparent identity to Ben Davis in tree and leaf characteristics as studied by Shaw (25). The same thing applies to the Gallia Beauty herein classified by the author as a red sport of Rome Beauty.

Since a complete chronological record of bud sport discovery in the apple up to 1931 has been published by Shamel and Pomeroy (24), only a brief summary is given in this paper, mainly for the purpose of showing the great progress taking place during the past year.

Bud mutations in deciduous fruits may be artificially divided into two classes, namely, (1) variations which result in a *less* desirable fruit,

from the commercial standpoint, and (2) variations which result in a *more* desirable fruit, due to the presence of a better horticultural character.

In addition to these two classes, a third might be added to include those variations affecting portions of the tree other than the fruit (such as leaves and blossoms), having little or no effect on the fruit or the fruit grower, except where actual dwarfing of the tree occurs (2).

Under Class I, we can list characters such as russeting, striping, failure to color, abnormal sizes and shapes, non-productivity, and barrenness. Class II mutations would include such characters as earlier and increased color of fruit, desirable size change, early and late blossoming, early and late ripening, and russeting in some varieties of pears. The present survey is based largely on the types of bud mutations which are likely to be of most value to the fruit grower. The author has been primarily interested in securing information and records on the red color of the apple, as this seems to offer for the time being at least, the most fruitful field of variety improvement from the commercial standpoint. In time, other types of mutation may be of greater consequence. In certain varieties of nearly all deciduous fruits, late blooming and early or late ripening strains may be of considerable value. The selection of variety mutations with different times of ripening may be particularly valuable and may parallel to some extent the progress made along this line by hybridization. A rather interesting example of this situation is reported by Nebel (17) concerning early and late ripening Gravenstein strains in Germany.

Only eight apple color sports, comprising five varieties, had been recorded prior to 1911. During the next 10 years, only four color mutations and one variety were added to the list. Ten years later, however, (1931) there was a different story to tell. The color sport list had by August 15, 1931, climbed to 143 origins comprising 26 apple varieties (24). One year later, the list had reached a total of 202 distinct increased red color strain origins in 30 apple varieties (5). Since that time even more have been added making a total of 228 red strains in 35 varieties, as is shown in Table I.

TABLE I—Distribution of Increased Color Mutations Among Apple Varieties

1. Delicious—55	13. Jonathan—4	25. James Greve—1
2. Winesap—30	14. Twenty Ounce—4	26. Rambo—1
3. Rome Beauty—19	15. Red Astrachan—3	27. Ribston—1
4. Northern Spy—13	16. Tompkins King—3	28. Shiawassee Beauty—1
5. Fameuse—12	17. Willow Twig—3	29. Summer Queen—1
6. McIntosh—11	18. York—3	30. Summer Rambo—1
7. Duchess (Oldenburg)—10	19. Ben Davis—2	31. Transcendent Crab—1
8. Gravenstein—10	20. Chenango—2	32. Westfield (Seek-No-Further)—1
9. Stayman Winesap—10	21. St. Lawrence—2	33. Williams—1
10. Stark—8	22. Wealthy—2	34. Winter Banana—1
11. Spitzenburg (Esopus)—5	23. Bramley—1	35. Wolf River—1
12. Baldwin—4	24. Hyslop Crab—1	Total—228

Increased color sports probably occur rather evenly in the red varieties of apples. They have been found, however, in almost direct proportion to the amount of plantings or propagation of such varieties, altered somewhat by the varied intensity of observation. This shows why we have found more of these color mutations in Delicious and Winesap than in others, and in the West more than in any other section of the country. For example, among the 52 recorded color sports of Delicious, 36 were found in Washington, four in British Columbia, three in New Jersey, two each in Colorado, Illinois, and New York, and one each in Delaware, Maine, and Tasmania (Australia). All the 29 color sports of Winesap, and 13 of the 18 Red Romes were found in Washington. On the other hand, most of the Northern Spy sports have been found in Michigan and New York, where that variety is more commonly grown.

TABLE II—DISTRIBUTION OF NON-COLOR MUTATIONS AMONG DECIDUOUS FRUIT VARIETIES

Nature of Mutation	Fruit	Number Varieties Affected	Number Mutations Recorded
Increased size (Giant type)	Apple	15	23
	Pear	2	9
	Sour Cherry	1	1
Abnormal shapes:* flattened, angular or oblong	Apple	10	13
	Peach	4	4
	Pear	1	2
	Sweet Cherry	1	1
Green color, or failure to color	Apple	4	7
	Sweet Cherry†	3	4
Russeting	Apple	6	9
	Pear	4	12
Early ripening	Apple	5	8
	Peach	6	10
	Cherry	1	1
	Prune	1	2
Late ripening, or long hanging	Apple	2	2
	Cherry	2	3

*Some of these form variations may be chimeras of normal and giant strains.
†In Sweet Cherry loss of color is not complete, a narrow band of color remaining in the form of a stripe at the suture and usually extending into the flesh.

It begins to seem possible that these variations may be found almost anywhere, when they are really sought. In Washington, for instance, where most of the recent findings of apple color sports have been made, a "Bud Sport Show" has been held for the last 3 years in connection with the annual meeting of the State Horticultural Association, serving as a stimulus to orchard owners, apple pickers, and fruit inspectors in search for these new types of fruit.

Types of mutations other than early and added fruit color are also becoming so numerous, that the author will not attempt to present an accurate list of them. Included in the totals (Table II) are the

recordings of pear mutations by Merrill (16) and Shamel et al (22); stone fruit mutations, by Weldon (29) and Shamel et al (23) largely in peach varieties in California; but only a portion of the miscellaneous fruit mutations recorded by Drain (10), Gardner, (12), and Gibson (13) in Michigan. Table II outlines the field covered by these non-color types of bud variations.

In addition to those contained in Table II, a few other miscellaneous instances of bud variations might be mentioned. In California, barren limbs have been noted rather frequently in the sweet cherry. Unproductive strains have likewise been found in the peach and sour cherry. Recent studies of the J. H. Hale peach indicate that there are one or two self-fruitful strains of this variety. Partial mutations or chimeras, usually observed as sectional striping, are very common in the apple, and sometimes found in the pear. In addition to these variations affecting the fruit, there have been discovered and recorded various types of leaf and blossom mutations in many deciduous fruit varieties, particularly in the stone fruits. Length of stems in the cherry has also shown some variation which seems capable of being propagated.

This summary of deciduous fruit mutations cannot be given as absolutely accurate. Many mutations which occurred in the past were never discovered, or even if noticed, they were not recorded before they became lost or destroyed. Furthermore, new mutations are being added so rapidly such a list would be out-of-date almost the day after it is made. There is also some lack in accuracy, because not all variations have been found at their points of origin (as twigs or limbs), and consequently a few duplicates may exist from unintentional propagation prior to the discovery of the mutation. All tree origins would fall into this class, and it will take years of careful investigation and study to eliminate such duplications.

This points to the great need of testing scientifically the various mutations within a single variety, not only that the duplications may be detected, but that the inferior sports may be eliminated and the superior ones pointed out and saved for propagation. This work has received a small start in the United States under federal and state supervision, but there is much to be done and as Dorsey (8) aptly puts it, "the technique of testing bud sports needs study."

Bud mutations are of great importance to the fruit grower, the fruit dealer and the nurseryman. By means of the color mutation, the fruit grower has been able to increase the color level of his crop more than he could have accomplished by the combined results of all his cultural practices. The careful nurseryman is already attempting to propagate the best strains he could get and eliminate the inferior ones for the sake of his business, if not for the benefit of the fruit growers. The fruit dealer is having his problems with the competition between new sports and their parent varieties, sometimes even under the same name.

The problem of red strain nomenclature presents itself along with the discovery and propagation of these color mutations. At present

there is no system whatever in naming these sports and consequently there has appeared a wide variety of names. For example, we have red Delicious sports called "Red Delicious," (though sometimes this name is also used to designate the normal Delicious from the Golden Delicious); "Richared," a name coming from the discoverer of a particular strain; "Starking," illustrating a nursery derivation of a name; and also "Redwin" and "Ready Red," names which have no connection with the Delicious variety except as they attempt to describe each particular sport.

The mechanism of somatic or bud mutation in the deciduous fruits has not been given much study, but is believed by Dorsey to be similar to non-disjunction affecting one or more factors, or one or more chromosomes. A horticultural character such as color may therefore be expressed by a large number of factors, regardless of the number of chromosomes which carry them. It seems probable that in most cases a color mutation is confined to the epidermal layer only, although in a few cases red streaking in the flesh of the fruit has been noticed. Inasmuch as increased color is invariably associated with earlier coloring, and takes place in different instances as a *heavier striping,* or is laid on as a blush in the beginning, the mechanism of the color mutation may be more complicated than has formerly been considered. This added color, moreover, is not always confined to the fruit, as increased red coloring is also noticeable in these color sports on the bark of young shoots and on leaf petioles, particularly in nursery trees.

In two or three apple varieties, it is not known definitely that the solid or blushed red type arose from the striped type, rather than vice versa, because discovery was made that both types were widely distributed subsequent to the death of the original tree of the variety. Castle (7) for instance, reported the existence of two distinct strains of the Williams apple in 1914. One of the earliest descriptions of this variety by Downing (9) over 80 years ago, must have been made following the death of the original tree, so that his apparent description of the solid red type cannot be taken as absolute proof of the non-existence of the striped type at that time. In considering the McIntosh variety in which the same two color types commonly exist, Palmer (18) takes the view that the solid red strain was the original one and observes that more variations occur from the solid red to the striped form, than from striped to solid red. The author takes the opposite view, however, based on the fact that many of these variations described by Palmer apparently occur on chimeral trees, and also on the fact that the oldest living McIntosh trees observed in eastern United States are of the striped strain. The Fameuse apple is a third variety in which the original color type is not recorded. In most apple varieties the blushed or solid red type is considered advantageous. The most outstanding exception to this rule is in the Gravenstein variety.

We have considered in this paper only the mutation which affects at least one entire bud in which all the tissue beyond a certain point will be the same. As brought out by Kraus (15), bud mutations may occur at any stage of growth, and affect only a part of a bud, flower,

or fruit. Among a few of our deciduous fruits, such as the apple, this form of somatic mutation called a chimera, is not uncommon. Chimeras may be of either the sectorial or mosaic types, the former occurring more frequently.

Origins of the bud mutation have in some cases been associated with unusual environmental conditions such as a fire or the breaking down of a tree, causing heavy vegetative growth of shoots. This seems to be in line with what a few workers find with induced mutations in other plants as a result of extreme heat or extreme cold. In other cases there is seemingly no abnormal growth condition whatever, and the sport limb may be on any side of the tree or on the inside, and of any size from one extreme of an entire half of the tree to the other extreme of being a small twig on the outermost end of a large branch. This distinction, of course, lies in the time of origin in respect to the age of the tree.

It is very interesting to note that Emerson (11), as far back as 1913, suggested that the possibility of bud mutations seemed great enough to warrant experiments in treating the growing parts of plants to induce gene changes. Results which have been obtained by Stadler (26) with various annual plants, Goodspeed and Olson (14) with tobacco, Scott (20) with roses, and others which bear this out, strongly suggest that bud mutations through germinal variations might be induced in fruit trees as they have in other plants by the irradiation with X-rays. Stadler in particular believes that with the complex heterozygotes found in most of our deciduous fruits, vegetatively propagated, and having a long reproduction cycle under hybridization, the selection of these bud variations, naturally and artificially produced, offers a much simpler method of improvement. It is probably safe to add that induced mutations would not show a greater proportion of unfavorable variation than we find among the natural or chance mutations.

Future possibilities along this line of deciduous fruit improvement already stimulated by the Plant Patent Act, seem almost unlimited. It is of interest that of the first 30 plant patents granted, 10 had their origin as bud sports (27).

In addition to new or changed characters heretofore mentioned, it is entirely within the realm of possibility that other types of mutations affecting yield and vigor of the tree as well as texture and quality of the fruit will be found. Already a few instances of these changes have been noted, such as Sartorius (19) reports in the higher yielding strain of Froelich's Sylvaner Grape. Improvements such as these, however, will be more difficult to observe and verify until a highly systematic and more scientific search is made for them and reliable methods developed for their measurement and evaluation.

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The Value of the Pollen of Some of the Recently Introduced Apple Varieties

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THE interest in this subject on the part of eastern fruit growers would seem to warrant publication of such data as have been obtained during the past 3 years, even though a precise rating of the varieties as pollinizers is not yet possible. Some information along this line has been presented in the recent publications of Latimer (3), Knowlton (2), Burrell and Parker (1), MacDaniels and Burrell (5), and others. Attention in the present studies was directed chiefly to the value of pollen of some of the introductions of the New York Agricultural Experiment Station at Geneva, most of them being McIntosh crosses. Incidentally, the results with a number of older varieties are also included. The pollens were tested on trees of the varieties McIntosh, Rhode Island Greening, Northern Spy, and Cortland.

The branch-unit method, the merits of which have been considered in detail in previous publications by MacDaniels (4) and Murneek (6), was used throughout. It must be borne in mind that the factor being tested is the effectiveness of the pollen in causing fruit to set. The abundance of pollen produced, the date of bloom, the tendency toward alternation, the commercial desirability of the fruit, and the suitability of the variety for the region must also be considered in choosing a pollinizer.

From the data given in Table I it appears that of the pollens used on two or more branch units the following were fairly consistent in producing a satisfactory set, namely, Twenty Ounce, Opalescent, Duchess, Red Duchess, and Cortland. Others used two or more times which gave lower sets or more erratic results were Bismark, Early McIntosh, Milton, Lobo, and Kendall. Though used but once the following produced satisfactory sets, namely, Macoun, Ben Davis, Red Astrachan, Carleton and Medina.

The results of similar tests conducted in the Champlain Valley in 1932 are briefly summarized in Table II. The McIntosh crosses, Macoun, Lobo, Milton, and Early McIntosh, as in Table I, appear to have pollen of considerable value in causing McIntosh to set fruit, yet not of the highest order of potency. It is interesting that Medina resembles its parent, the Delicious, in having very effective pollen.

In another series of trials pollen of the varieties Kendall, Red June, Early McIntosh, Lobo, Carleton, Milton, Red Delicious, Melba, and Terry were applied to single uncovered unit branches in a McIntosh orchard poorly supplied with pollinizers. In all cases the hand pollinated branches out-yielded the adjacent checks, the average percentage set being 27 for the former and 13 for the

TABLE I—SET PRODUCED BY VARIOUS POLLENS ON BAGGED McINTOSH BRANCHES, WESTERN NEW YORK, 1930–1932*

Pollen Variety	Total Number Spurs	Per cent Spurs Blossoming	Number Spurs with Fruit September	Per cent Blossoming Spurs with Fruit September
		(1930)		
Twenty Ounce	101	23	7	30
Red Astrachan	117	44	21	40
Kendall	153	39	3	5
Ben Davis	161	26	14	33
Bismark	112	64	13	18
Opalescent	114	66	34	45
Early McIntosh	121	55	10	15
Duchess	122	64	26	33
Open check	122	65	5	6
Bismark	151	45	21	31
McIntosh	126	44	1	2
Opalescent	102	71	25	35
Duchess	138	51	28	39
Open check	74	55	4	10
Open check	149	52	5	6
		(1931)		
Open check	116	46	3	6
Red Duchess†	165	35	31	54
Kendall	173	42	29	40
Early McIntosh	148	60	19	21
Cortland	95	49	27	57
Kendall	162	44	12	17
Red Duchess	195	33	27	42
Milton	128	34	4	9
Early McIntosh	175	45	14	18
Cortland	159	49	19	24
Open check	118	39	2	4
Open check	177	53	13	14
Macoun	144	56	33	41
Lodi	104	51	24	45
Lobo	141	45	9	14
Carleton	206	34	27	38
		(1932)		
Milton	119	58	41	59
Early McIntosh	119	61	30	41
Selfed	123	55	0	0
Twenty Ounce	116	78	42	48
Medina	108	71	49	64
McIntosh	105	78	2	2
Twenty Ounce	184	72	62	47
Early McIntosh	112	56	42	67
Lobo	115	82	58	62
Milton	114	34	24	61

*Horizontal lines separate the different trees.

†Red Duchess from Daniels Nursery, Long Lake, Minn.

checks. Red Duchess pollen showed greater potency than any of the others.

TABLE II—SET PRODUCED BY VARIOUS POLLENS ON BAGGED MCINTOSH BRANCHES, CHAMPLAIN VALLEY, 1932

Pollen Variety	Number of Branch Units Used	Average Number Spurs with Fruit per Unit Branch	Average Per cent of Blossoming Spurs Maturing Fruit
Medina	2	27	40
Macoun	3	21	23
Lobo	6	15	20
Milton	5	12	14
Early McIntosh	6	14	14
Open check	11	21	32

The data in Table III indicate that all varieties tried are effective pollinizers for Northern Spy. Macoun because of its late blooming is promising as a pollinizer for this variety. Hubbardston is known to be a good pollen variety and is included for comparison. The heavy set with Macoun pollen in 1932 is a good example of a high percentage set on a branch with a low percentage of spurs blooming.

TABLE III—SET PRODUCED BY VARIOUS POLLENS ON BAGGED NORTHERN SPY BRANCHES, 1930–1932*

Pollen Variety	Total Number Spurs	Per cent Spurs Blossoming	Number Spurs with Fruit September	Per cent Blossoming Spurs with Fruit September
	(1930)			
Spy	131	31	0	—
Orenco	112	31	17	50
Macoun	185	35	16	25
Hubbardston	125	35	23	52
Macoun	156	47	18	25
Hubbardston	145	41	12	22
Orenco	106	50	18	34
Spy	156	39	0	—
Open check	116	31	2	5
Open check	101	54	11	20
	(1932)			
Spy	123	54	0	0
Macoun	153	58	48	54
Macoun	92	24	22	100
Spy	105	61	1	2

*Horizontal lines separate the different trees.

The results from using some of these pollens on Rhode Island Greening are shown in Table IV. Since each pollen except Milton was used on but a single branch, the only safe deduction would be that all varieties tried have some value as Rhode Island Greening pollinizers. Positive sets are of course much more significant than negative results when small numbers are concerned. The relatively heavy set on the selfed branch in 1932 is another example of high percentage set correlated with a light bloom.

TABLE IV—Set Produced by Various Pollens on Bagged Rhode Island Greening Branches*

Pollen Variety	Total Spurs	Per cent Spurs Blossoming	Number Spurs with Fruit September	Per cent Blossoming Spurs with Fruit September
		(1930)		
Opalescent	113	56	28	44
Twenty Ounce	152	56	11	13
Ben Davis	111	63	20	29
Selfed	177	14	0	—
Open check	82	38	11	35
Open check	162	46	3	4
		(1931)		
Early McIntosh	150	52	27	35
Milton	119	75	19	21
Kendall	198	58	11	10
Selfed	163	39	2	3
Open check	262	67	17	10
Red Duchess	169	79	19	14
Open check	212	49	10	10
		(1932)		
Twenty Ounce	207	54	29	30
Macoun	184	80	40	27
Open check	186	69	44	34
Selfed	167	26	7	16
Milton	167	56	33	35

One tree used each year.

A similar group of pollens was tested on Cortland with the results presented in Table V. An interesting characteristic of this variety is the tendency for a rather low percentage of its spurs to bloom in consequence of which, a high percentage of its blossoming spurs set fruit.

From Table V, it is apparent that Kendall, Lobo, and McIntosh are satisfactory pollens for Cortland, while Early McIntosh is consistently inferior to the other kinds tested.

Discussion

A study of these results indicates that in general the pollens of the McIntosh crosses are not equal to those of such varieties as Delicious, although they do have considerable value. Possibly Early McIntosh pollen is consistently less effective than that of other varieties tested. From a practical standpoint it can be said that on the basis of our rather meager knowledge, Early McIntosh and Kendall might be used as pollinizers for McIntosh or Cortland, if planted in liberal numbers but should not be relied upon where it is desired to use the fewest possible trees as pollinizers.

The tendency for light-blooming branches to set fruit on a larger percentage of the blossoming spurs than is the case with heavy blooming branches has been responsible for some of the variation in results. Another factor has been non-uniform bearing during

TABLE V—SET PRODUCED BY VARIOUS POLLENS ON BAGGED CORTLAND BRANCHES, 1931–1932*

Pollen Variety	Total Number Spurs	Per cent Spurs Blossoming	Number Spurs with Fruit September	Per cent Blossoming Spurs with Fruit September
(1931)				
Lobo	137	37	22	43
Open check	104	51	23	43
Kendall	127	35	22	49
Early McIntosh	79	49	4	10
McIntosh	151	34	27	53
Early McIntosh	152	47	20	28
Open check	111	39	12	28
McIntosh	139	25	17	49
Kendall	133	30	19	48
Lobo	123	37	21	47
(1932)				
Lobo	71	35	14	36
Open check	108	44	12	26
Selfed	140	24	5	15
Early McIntosh	198	36	0	0
McIntosh	143	43	17	28
McIntosh	97	38	20	54
Ben Davis	108	47	25	49
Selfed	109	61	3	5
Open check	104	34	7	20
Early McIntosh	118	43	3	6

*Horizontal lines separate the different trees.

the preceding year. Some factors bringing about lack of uniformity in branches on the same tree are impossible to overcome. However, this one could be controlled at least in part if unit branches were selected a year in advance and either bagged to prevent setting or allowed to set normally and then thinned very early in the season to a uniform load. Most consistent results are obtained with the branch unit method in orchards of good vigor which have not borne heavy crops during the preceding year.

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An Improved Device to Facilitate Pollen Distribution by Bees

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In continuing work previously reported, on the use of a device by which prepared pollen was made accessible to honey-bees, in an attempt to have them carry it and effect pollination of apple blossoms during their normal foraging flights, certain improvements have been made. The pollen dispenser used in tests at Chazy Orchards, permits incoming bees to enter the hive directly, while only outgoing bees have access to the pollen. This arrangement effects greater economy in pollen and seems not to interfere with normal bee activity.

The pollen dispenser (Fig. 1) consists essentially of two pieces of dressed 1-inch lumber, in width 2⅞ and 2⅜ inches, respectively, and 14⅜ inches long, for a 10-frame hive (shorter or longer for other hive widths), channeled and fitted with two narrow wire screen baffles attached to the upper member (1) arranged to alternate with the longitudinal ridges in the lower member (2), together with appropriate screen deflectors. Bees seeking an exit approach the light, crawl over the rear rim of 2, pass under the rear screen baffle of 1, over the sharp middle ridge of 2, under the inner baffle of 1 into the pollen chamber. From the pollen chamber they bear right and pass up and out of the screen-lipped exit. Incoming bees promptly seek the entrance immediately below the exit and enter, passing through the flat screen-conduit into the hive several inches toward the rear.

Three of these devices were used in the following test. Six 8-year McIntosh trees were selected and numbered from 1 to 6. Trees 1 to 4 inclusive were of as nearly equal size and bearing capacity as could be estimated. Trees 5 and 6 were somewhat larger, but well matched with each other. The trees were assigned as follows, namely, Nos. 1 and 5 to be checks having bees but no outside source of pollen; Nos. 2, 3, and 6 to test the pollen dispensers; and No. 4 to receive a pollen bouquet. The pollen used in the dispensers was a mixture of Delicious and Tolman, both of which varieties are very effective in causing McIntosh to set fruit. The bouquet consisted of Wealthy and Oldenburg blossoms.

Each tree was enclosed in a cheesecloth cage before any blossoms opened, and a typical branch with from 57 to 88 blossoming spurs was bagged in cheesecloth on each tree. At full bloom, about three blossoms on each spur of this bagged branch were hand-pollinated with tested pollen of mixed varieties as a measure of the tree's ability to set fruit, when cross-pollination was not a limiting factor.

Normal bee colonies (4 quarts or more of bees each) were selected for use. Except in the case of tree No. 4 (bouquet), where

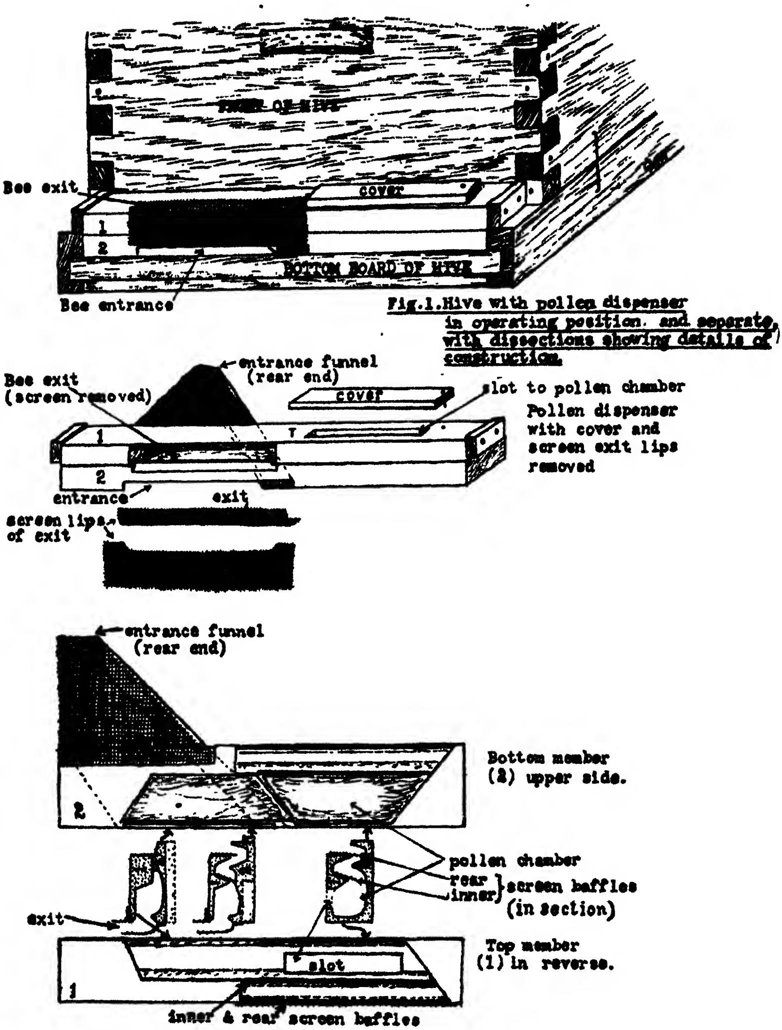

FIG. 1. Hive with pollen dispenser in operating position and separate, with dissections showing details of construction.

an accident interfered, the bees were confined before use to prevent possible contamination. Weather conditions were favorable when the earlier blossoms opened, but after pollen was introduced intermittent showers kept blossoms wet much of the time. As twig and foliage burning occurred, possibly due to spraying as the trees were being caged, there may have been an unfavorable influence on the set of fruit.

TABLE I—Yield of Caged McIntosh Trees with and without Pollen Dispensers

Tree No.	Treatment	Time Bees were Liberated in Cage	Previous Period of Confinement in Hours†	Per cent Blossoming Spurs Maturing Fruit on Hand Pollinated Branch	Actual Yield on Tree (Pounds)	Theoretical Yield of Tree (Pounds)*
1	Check, bees only	As first blossoms opened	30	24	7	7
2	Bees and dispenser	About 40 hrs. after first blossoms opened. Trees almost full bloom	70	13	27	50
3	Bees and dispenser	As first blossoms opened	70	12	14	28
4	Bees and pollen bouquet	About 40 hours after first blossoms opened. Trees almost full bloom	0	32	41	32
5 (Larger tree)	Check, bees only	As first blossoms opened	30	43	15	15
6 (Larger tree)	Bees and dispenser	About 40 hours after first blossoms opened. Trees almost full bloom	70	14	90	276

*Calculated on assumption that set of hand-pollinated branches measures productive capacity of respective trees. Yield of trees Nos. 2 to 4 is adjusted to check tree No. 1; that of tree No. 6 is adjusted to check tree No. 5.

†Pollen supplied to all three dispensers 1 day after bees were liberated in cages Nos. 2 and 6. Hence extensive selfing preceded cross-pollination.

In exit through the pollen dispensers, bees were seen to carry pollen adhering to hair on their bodies and legs. Their foraging flights were at first normal but the frequent visits soon depleted the flowers of pollen, after which some bees collected pollen from the pollen dispenser, flew out and immediately re-entered the hive.

The treatments given and results obtained are summarized in Table I. Trees Nos. 1 to 4 inclusive are comparable, but trees Nos. 5 and 6 are best considered as a separate pair, as previously noted. The actual yield is much higher in the case of trees Nos. 2 and 3, equipped with pollen dispensers and tree No. 4 provided with a bouquet than in the case of check tree No. 1 which had bees only. Likewise, tree No. 6 which had a pollen dispenser greatly outyielded the corresponding check tree No. 5. These differences become much more striking if we assume that the yield of the hand-pollinated branches measures the productive capacity of the respective trees, and calculate what the yield of the treated trees should have been, had they been possessed of the same productive capacity as the corresponding check trees. Chief reliance should be placed on the actual yields, however.

Dichogamy—An Important Factor Affecting Production in the Persian Walnut

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ALTHOUGH Delpino (1), Kerner and Oliver (2), Jessup (3), and Delong (4) mentioned dichogamy in Juglans, there was great diversity in opinion as to its extent and type. Many growers in the West have believed that light crops were due in some cases to sterility or lack of compatibility of pollen and pistil, or that pollination under natural conditions was inadequate in some way. Others believed that light crops could not be ascribed to any pollination factor. Although a limited amount of observational evidence was advanced to substantiate the various opinions, there had been no experimental studies upon which conclusions could be established regarding the relation of pollination to crop production.

In 1920 experiments were started and collection of data begun to determine whether walnut varieties were self-fertile, whether inter-sterility or incompatibility of pollen and pistil occurred, and whether dichogamy was responsible for light crops or complete crop failure in any of the commercial varieties. Details of the methods used are given in a forthcoming U. S. Department of Agriculture bulletin. Some phases of the investigations have been discussed in a previous article (5).

Briefly the findings to date may be summarized as follows: (1) All varieties are self-fertile. (2) All varieties are inter-fertile. (3) Inter-fertility exists between all varieties of *Juglans regia* and other species tested, including *J. hindsi, J. californica,* and *J. sieboldiana.* (4) Dichogamy is common.

In general, it may be said that light crops cannot be attributed to self-sterility, inter-sterility, or lack of compatibility between pistil and pollen. On the other hand, dichogamy is often the cause of crop failure in orchards planted to one variety, or to more than one variety when the blooming period of each variety differs from that of the others in the orchard.

Great variation was found in the extent and types of dichogamy occurring in the genus. Some varieties tend to be protandrous and others to be protogynous. Protandrous varieties include the Concord, Eureka, Franquette, Golden Nugget, Grove, Grenoble (French Mayette), San Jose Mayette, XXX Mayette, Payne and Praeparturiens. Among protogynous varieties are the Erhardt, Lucretia, Meylan, Pride of Ventura, and most of the Santa Barbara Soft Shell seedling types. Protandry was most pronounced in the Franquette, San Jose Mayette, Payne, and Eureka varieties. The El Monte, Willson, and Persian were difficult to classify.

The fact that some varieties are protandrous and others protogynous in tendency accounts no doubt for the differences in opinion

held by previous investigators regarding the type of dichogamy present in *Juglans regia*. If there were no variation in dichogamy in any variety it would be easy to plan an interplanting of varieties to insure proper pollination. Other factors, however, enter into the matter.

Dichogamy varies with the age of the tree. In the varieties studied it is more complete in young than in old trees. This apparently accounts for the fact that some varieties (for example the Franquette) do not bear well until the trees are fairly old. Variation in dichogamy with age of tree is especially pronounced in some of the protandrous varieties.

Climate has a very definite effect upon dichogamy. Experiments in California show that the catkins[1] respond more quickly to sudden spells of warm weather than do the terminal growths bearing the pistils, particularly after a cold winter. When warm weather continues for a number of days, the catkins in protandrous varieties may develop so much faster than the pistils, that no pollen is left by the time the pistils become receptive. On the other hand, in protogynous varieties such a season hastens the development of catkins so that the difference in time of bloom between catkins and pistils is lessened. When, after a warm winter, the blooming season is cool, protogynous varieties may develop pistils so far ahead of the catkins that the receptive period may be over before pollen is produced, while in protandrous varieties the coincidence of blooming of catkins and pistils is increased. So great is the effect of weather upon the blooming habit that a protandrous variety may in some seasons actually become protogynous, or, the season may be such that protogynous varieties become protandrous. In the varied climates found in California all degrees of protandry and protogyny occur. More specifically, dichogamy is affected by temperature, amount and intensity of sunlight, winds, air drainage, humidity of the atmosphere, soil moisture, and perhaps such factors as type of soil and rootstock.

It is evident that dichogamy varies not only according to the season, but according to geographic location. In general, coastal regions emphasize protogyny, and decrease protandry, while in the interior valleys protandry is pronounced and protogyny diminished. During the same season a variety having a protogynous tendency (such as Placentia) may be protogynous at Ventura on the coast and protandrous at Chico in the northern part of the Sacramento Valley. On the other hand, a variety having a protandrous tendency, such as Franquette or Payne, may be completely protandrous at Chico and nearly or wholly protogynous at Ventura. Actually, then, a protandrous variety would be much more likely to pollinate itself in coastal districts than in the interior, and a protogynous variety would be more likely to pollinate itself in the interior than

[1]The term "catkin" is applied in this paper to the staminate flowers only.

on the coast; therefore one would at first thought be inclined to conclude that protogynous varieties should be grown in the interior and protandrous varieties in coastal regions. Other considerations, however, make this impracticable. It happens that among the superior commercial walnut varieties most of the early bloomers are protogynous in tendency while many of the late bloomers are protandrous. Many of the earliest bloomers are unsuited to the interior because of the damage likely from late spring frosts. In some of the coastal sections (especially in southern California), the growing season for late blooming varieties is so short that the crop does not have time to mature properly.

Because of the variations in the completeness of dichogamy due to climate, season, and locality as well as to variety, it is not possible to foresee exactly what will be the effect of planting any combination of varieties unless blooming data have been kept in the locality for several years. However, varieties are fairly consistent in their time of bloom with relation to one another. Although in a given locality the dates of bloom of all varieties are closer in some seasons than in others, the sequence of blooming remains about the same; therefore a rough classification into early, intermediate, and late bloomers has value in planning a planting to favor pollination. Though the amount of inter-pollination secured will vary from year to year, and will not be the same in different districts for the same group of varieties, the proper grouping of varieties is likely to prove helpful in most years if not in all, a fact borne out by data collected from commercial orchards for the purpose of comparing walnut orchards consisting of several inter-planted varieties with those consisting of a single variety only.

Because no variety or locality is always free from dichogamy, it would appear that any grouping is better than none at all, but, to secure the best results, careful grouping based on data collected for the district is necessary. Inter-planting early and late varieties is not advisable because in some seasons their blooming periods do not overlap. Probably the best combinations are those which bring together early and intermediate bloomers, or intermediate and late bloomers, or all three. The fact must be considered, however, that the grower has to limit the number of varieties in his orchard to a few most suited to his purpose. The matter is further complicated by the consideration that when late varieties are grouped they are likely to suffer from the same pollination trouble at the same time. This is true to a somewhat less extent of intermediate, and of early bloomers. Furthermore, when protandrous varieties are planted together for pollination purposes, many of the pistils of the latest blooming variety must go unpollinated, and when protogynous varieties are grouped many of the pistils of the earliest blooming variety will be unpollinated. The ideal arrangement would be to plant together a protogynous variety and a protandrous variety blooming at the same time, but in practice this is difficult because protogynous and pro-

tandrous varieties of commercial merit blooming simultaneously are few, and the two types are not suited to the same locality. For a number of years a careful search has been made to secure better pollinators for the leading commercial varieties. The protandrous variety Payne, and the somewhat protogynous Lucretia, seem to go well together. Frostfighter appears to be an excellent pollinator for Franquette in some localities, and Meylan in others. Certain strains of the California Black, "Bolivian Black," Japanese walnut, and some Persian seedlings may also be desirable pollinators for some of the commercial varieties, but records must be kept for a number of years before their value can be stated positively.

Grafting-in of pollinating varieties has already given remarkable results in orchards in which unproductiveness was due to dichogamy. Artificial pollination has greatly increased crop production in some dichogamous orchards. Incomplete or partial dichogamy generally results in considerable loss of crop. In such cases provision should be made for proper pollination.

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Artificial Pollination as a Means of Increasing Production in Commercial Persian Walnut Orchards

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Results are here reported on artificial pollination of dichogamous Persian walnuts in California, as a temporary measure, pending the blossoming of grafts or of interplanted pollinating varieties.

Methods

Several methods of artificial pollination were tried on a commercial scale. One consisted in cutting catkin-bearing branches from trees and placing their cut ends in buckets of water which were hung in the trees to be pollinated. It was found that catkins which had started growth could be forced by this means and would disseminate pollen. When the winds were favorable the crop was increased by the procedure. Many times, however, the pollen produced by the forced catkins gave a low viability test by laboratory methods. On the whole the method proved cumbersome and expensive.

In another method mature catkins were dried on sheets of wrapping paper and the pollen shaken out. It was applied to the trees by means of a hand blower. Though increase in yield resulted, many pistils were not pollinated, because they were not receptive when the pollen was applied. This fact, together with the expense, inconvenience, and labor involved, rendered this method unsuitable to commercial orchards.

A method that proved more satisfactory consisted in picking catkins, placing them in bags made of mosquito netting, and suspending these bags in the tops of the trees to be pollinated. At first only catkins with some anthers beginning to dehisce were picked. Later it was found that catkins harvested even when less than one-half the length of matured catkins produced pollen abundantly after they had dried in the trees for several days. Thereafter catkins of all stages of maturity were used. It proved convenient to pick the catkins into large paper bags. If these bags were left open or the catkins placed in other open containers, they could be kept for several days. Kept in closed containers or heaped in quantities sufficient to prevent circulation of the air, they molded.

The bags in which the catkins were suspended were made of mosquito netting cut into pieces about 1 foot square. A double handful of catkins was placed upon a square of mosquito netting, the corners gathered up and tied to form the bag. Sewing was unnecessary. Next, the bag of catkins was tied to the end of a spool of string, and thrown into the top of the tree to be pollinated. The bag was caught in one of the topmost branches and the string tied to one of the lower branches. Every day a man went through the

orchard to tap the suspended bags with a fish pole to jar out the pollen. When catkins of all stages of development were placed in the bags an abundance of pollen was produced for at least 6 days, and sometimes for considerably longer. In the orchard in which the work was conducted help was plentiful and efficient. A crew of six men did the work from a truck in the field. One man cut the netting, another placed the catkins in the squares of netting, a third tied the bags, a fourth threw them into the tree, a fifth walking on the ground by the side of the truck tied the lower end of the string to a convenient branch, and a sixth drove the truck. In this way a large acreage was supplied with bags of catkins in a day.

Requirements for Successful Artificial Pollination

In order that artificial pollination may be successful, it is necessary (1) to find enough trees producing catkins at the time when the pistils of the variety to be pollenized are receptive. Cold storage of catkins until needed was only partly successful, probably because the best temperature has not been determined. (2) Weather during the pollination period must be suitable to cause the catkins hung in the bags to shed pollen. (3) There must be air currents to carry the pollen to the stigmas, and the quantity of pollen provided must be sufficient to guarantee efficient distribution over most of the pistillate blooming period. (4) There should be sufficient help to carry on the work promptly when the time is opportune.

Scope of the Experiment

The experiments were undertaken upon the Payne variety in three bearing orchards in the Linden district of California. Previous records showed that there was an abundance of *Juglans regia* seedling trees and black walnut (*J. hindsii*) trees available for supplying the catkins at the time needed. Ample help was available. Weather records showed the likelihood of steady winds from one direction at blooming time. This rendered it possible to establish check plots of small size. Although the Payne variety is normally not as completely dichogamous in the district as the Franquette or certain other varieties, partial dichogamy is common. Because of its location, one of the three orchards used is more pronounced in its dichogamy than most others in the locality. A total of 49 acres were included in the 1931 experiments. The orchards were within a mile of one another but differed in degree of dichogamy. In 1932 a young orchard of 40 acres was added to the experiments, making a total of 89 acres. The conditions obtaining in these orchards are as follows:

Orchard A. This orchard consists solely of the Payne variety on good soil. The trees in 1931 were 20 years old and were very large, having an average trunk circumference of 51 inches. The orchard was well managed and regularly sprayed for blight prevention.

TABLE I—SUMMARY OF RECORDS OF ARTIFICIALLY POLLINATED ORCHARDS

Year	Orchard	No. Acres in Check (Natural Pollination)	No. Acres Artificially Pollinated	Av. Yield per Acre of Checks (Pounds)	Av. Yield per Acre with Artificial Pollination (Pounds)	Per cent Increase Due to Artificial Pollination (Per cent)	Increased Income per Acre Due to Artificial Pollination (Dollars)	Age of Trees (Years)	Pollen Used
1931	A	1.62	16.38	1,460	3,360	130.01	263.27	20	
1931	A Unpruned	0.81	7.49	1,586	4,670	194.42	429.03	20	
1931	A Pruned	0.81	8.89	1,099	1,890	38.86	71.33	20	Mixture *Juglans regia*
1931	B	2.29	10.71	1,527.6	2,224.5	45.62	94.83	15	
1931	C	2.85	15.15	2,182	3,681	68.69	206.61	7	
1932	A	2.00	16.00	1,150	2,072.5	80.21	90.79	21	*Juglans regia*
1932	B	1.02	11.98	1,032.4	1,433.5	38.85	38.65	16	
1932	C	1.48	16.52	1,532.9	1,803.8	17.66	25.62	8	*Juglans regia* cold storage
1932	D	1.18	38.82	382.5	523.6	36.89	12.65	7	Black walnut

The trees had been more protandrous than most others of the variety in the district. The crop had been consistently low.

Orchard B. This orchard, also of Payne, is about a mile from Orchard A, and received similar soil and cultural treatments. The trees were 15 years of age, vigorous, and had an average trunk circumference of 45 inches. It had been somewhat less protandrous than Orchard A, but had not borne satisfactory crops except for an area on the west side near two large Eureka trees which produced some pollen at the proper time to pollinate the nearby trees.

Orchard C. This young orchard (grafted in 1924), of 18 acres is approximately 1 mile from Orchard A, and ½ mile from Orchard B. The trees are planted more closely than in orchards A and B. Orchard C consists of Payne interplanted with Grove in the ratio of three Payne trees to one Grove tree. Some benefit is derived from the cross-pollination, but the two varieties bloom at nearly the same time and have the same protandrous tendency, and are therefore not completely satisfactory, as frequently all pollen of both varieties is gone before all of the pistils have become receptive. In 1931 there appeared to be considerable overlapping in the blooming dates of the pistils and catkins.

Orchard D. This young 40-acre orchard has come into bearing recently. It consists of half Payne and half Grove trees.

In 1931 one bag of pollen was placed in every tree in every third diagonal row. In that year the windward side of the trees received more pollen and produced much heavier crops than the other side. To guard against this, in 1932 pollen bags were hung in every tree in the areas pollinated. Certain areas on the windward side or windward corners of the orchards were left unpollinated to serve as check plots for the experiment (see Table I).

Discussion of Results

In both seasons it was evident even to the casual observer that the trees in the artifically pollinated areas set more nuts than those under natural pollination. In 1932 the yields of all orchards in the district were considerably reduced by blight, even though well sprayed. Though the loss by blight was not ascertained it was probably the same on the pollinated areas as on the check plots, and the figures were compiled on that basis. During 1931 the cost per acre for all labor and materials in artificially pollinating the orchards was very low ($2.73 to $3.25 per acre). During 1932 the cost was $1.46 per acre. The blooming season in 1931 was very favorable to artificial pollination, being warm and sunny with mild winds. In 1932 rain and foggy weather prevailed during blooming time to such an extent that it seemed doubtful whether any appreciable pollination could occur. Only on 2 or 3 days did pollen seem to be shed from the bags of catkins.

The results are summarized on the acre basis in Table I. Increase in yield due to artificial pollination was greater in all the orchards

in 1931 than in 1932. However, in every orchard in both years there was some increase due to the artificial pollination, this increase ranging from 141.1 to 3,084 pounds per acre. In the older orchards, the yields were almost doubled and in one instance nearly trebled.

The estimate of greater income resulting from the increase in yield due to artificial pollination is based upon the warehouse price of 14 cents per pound returned to the grower in 1931, and an estimated price of 10 cents in 1932. It will be noticed that the increased income due to artificial pollination varied from $12.65 to $429.03 per acre and that in most cases the increase was over $50 per acre. Orchard A produced profitable crops in 1931 and 1932 for the first time in its history.

TABLE II—SUMMARY OF EFFECTS OF ARTIFICIAL POLLINATION UPON THE WALNUT AS DETERMINED BY PISTIL COUNT IN ORCHARD "A" 1931

Pollinated Trees or Check Trees	Number of Pistils Recorded	Number of Nuts Set	Percentage of Nuts Set
Pollinated trees	6,000	2,760	46.00
Pollinated trees	4,000	2,131	53.2
Check trees (open pollination under natural conditions)	4,400	870	19.7
Check trees (open pollination under natural conditions)	3,600	370	10.2
Trees two rows from pollinated trees	2,000	650	32.5

In 1930 the western part of Orchard A had been heavily pruned, therefore separate records were kept for the pruned and unpruned areas. The figures indicate that heavy pruning is likely to result in decreased yield the year following. In the winter of 1931, the rest of Orchard A was heavily pruned; therefore one set of records for the whole orchard was kept in 1932.

Table II shows the percentage of pistils which matured nuts in 1931 on Orchard A, on pollinated and unpollinated trees. The pistils on several branches of trees in the checks and in the pollinated plots in Orchard A were tagged and recorded. The results are of interest mainly in indicating the large percentage of nuts lost upon trees pollinated by natural means.

Although artificial pollination of the type decribed is not necessary for many walnut orchards, it is clear that in orchards suffering from dichogamy the crops can be greatly increased at little expense by the method described.

Parthenocarpy and Seed Abortion in Vitis Vinifera

By HELEN M. PEARSON, *University of California, Davis, Calif.*

BREEDING of improved varieties of seedless grapes is facilitated by knowledge of the existing types of seedlessness, the defects and merits which they show under various cultural conditions, and as much as possible about their heredity.

I.—PARTHENOCARPY IN THE WHITE AND RED CORINTHS

The most extreme type of defective ovule in *Vitis vinifera* observed up to the present time is that found in the Red and White Corinths. The Red Corinth is without doubt merely a pink variation of the White, as Sultanina Rose is merely a pink variation of the ordinary White Thompson's Seedless.

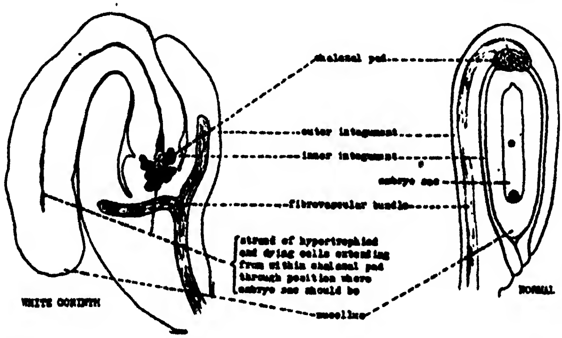

FIG. 1. Normal Vitis Ovule at Anthesis and White Corinth Ovule 2½ Days after Anthesis

The White Corinth has entirely misshapen ovules which never become anatropous. These ovules have only the outer integument, though the inner may be represented by meristematic swellings at the base of the nucellus. The single integument never forms any definite apical meristematic region, as do the integuments of a normal ovule. The nucellus is overgrown, much exserted beyond the integument in most cases, and usually curves back towards the base of the ovary after it has grown out from between the lobes of the integument. There is no embryo sac, but pollen tubes are found in the bases of the locules. The cells of the chalazal pad, which are normally in a compact group at the end of the fibrovascular bundle in the base of the nucellus, are scattered, and among them are always transparent hypertrophied and dying cells (the cells of the chalazal pad are normally all brown). A strand of defective cells apparently always extends from these defective cells through the nucellus as far as the position where the embryo saç mother cell should be found.

Usually there is but a single unbranched fibrovascular bundle running through the raphe to the chalazal pad in Vitis, but in the White Corinth ovule the bundle frequently branches.

In thousands of White Corinth berries examined by the author all of the ovules had the typical White Corinth shape, namely, a knob of external integument tissue, with the remnant of the nucellus hanging out of it, at the apex of the raphe, which is sometimes winged. Usually the ovule does not develop beyond its size at time of bloom, but rarely it shows some development. One cluster of exceptionally large Red Corinth berries on a ringed shoot had many ovules showing some enlargement, up to 3 or 4 mm in length. A number of them were sectioned and in the larger ovules conclusive proof was found that the single integument present was the external. Most of the cells of the internal epidermis of the single integument had divided with tangential walls and become extremely thickened in a way characteristic only of the cells of the internal epidermis of the external integument.

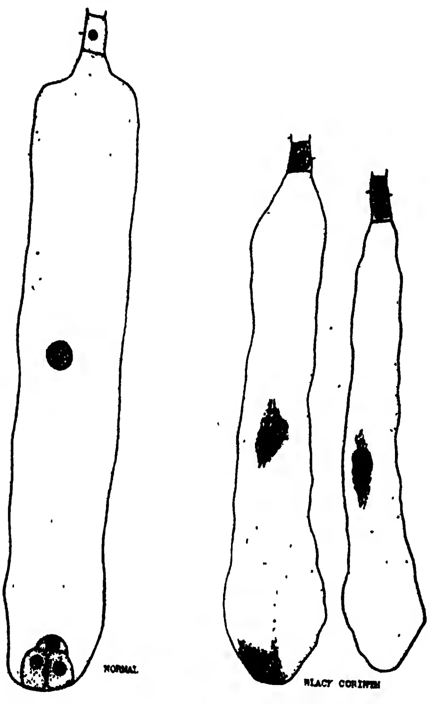

FIG. 2. Normal Vitis Embryo Sac and Typical Black Corinth Embryo Sacs at Anthesis with One or Two of the Nucellar Cells Above, Showing that these, too, are Degenerating in the Black Corinth.

II.—PARTHENOCARPY IN THE BLACK CORINTH

Parthenocarpy in the Black Corinth is apparently due to defective embryo-sac formation, and not to defects in any of the other issues of the ovule. This variety is one of the two seedless varieties of great commercial importance.

The normal contents of the embryo sac of Vitis at anthesis are an egg, two synergids, and a single fusion nucleus which has arisen from the union of the two polar nuclei. The antipodals have completely disappeared. The author has examined well over a hundred ovules of Black Corinth at and shortly after anthesis and has found only one in which the embryo sac could be considered as normal. The polar nuclei have practically never fused. The egg and synergids are seldom recognizable, but they may be represented

by a group of degenerating cells in the micropylar end of the sac. Most frequently there are three or four nuclei irregularly distributed in the embryo sac and often degenerating. The row of two or three cells directly below the embryo sac in the chalazal end frequently show signs of degeneracy.

Pollen tubes were numerous in the bases of the locules. In a very few cases a pollen tube had entered the nucellar and epidermal caps within certain ovules—only in ovules having some vestiges of an egg apparatus. In one case it had entered the almost completely disintegrated egg apparatus and the endosperm nucleus was in metaphase of its first division, signifying that it had been fertilized.

It does not seem likely that the growth of the pollen tube through the style has anything to do with the set of Black Corinth berries. Of 30 clusters emasculated and bagged, not one set, but this does not seem significant in view of the fact that 47 which were bagged either without emasculation or after having been emasculated and pollinated did not set either. Since temperatures are often 10 degrees C higher inside bags than outside, it seems likely that, although normal Vinifera berries set well inside the bags, the entirely seedless vegetatively parthenocarpic berries are too sensitive to such adverse conditions in the hot summer weather of Davis. Four clusters on ringed shoots which were emasculated set perfectly. It has not been proved, however, that in the absence of the nutritional stimulus of ringing the stimulus of pollination is not necessary in the Black Corinth. Ringing increases the set of vegetatively parthenocarpic berries in other varieties. At Davis, ringing increases set of shot berries on the variety Hunisa. These berries are certainly vegetatively parthenocarpic since the variety Hunisa is practically male sterile.

Ordinarily the Black Corinth berry weighs less than half a gram, and is very nearly round. It has no ovule development beyond the time of bloom, but makes more or less trouble from seediness. Examination of hundreds of clusters with many apparently seeded berries revealed but very few seeds which would sink in water. (The density of the seed is a rough measure of the extent of endosperm development.) In one very unusual cluster, however, in which there were 299 seeds, 170 were tested by placing in water and only 66 of these floated; 60 of those which sank were planted and 16 germinated.

Whenever the seed develops at all the berry enlarges obviously. Berries from eight very seedy clusters were found to present a continuous range in size from the size of the smallest seedless berries up to that of the berries in which the seeds were apparently fully developed. There was not a sharply discontinuous variation between the normal seeded and the completely seedless berries with only a few scattered berries in between, as there is when normal-seeded varieties such as Hunisa are graded.

Sections of 10 of the larger of the seeds from these eight clusters showed no sign of embryo or endosperm. In most of them,

large remnants of the nucellus had not yet disintegrated. In one, most of the central part of the nucellus persisted and in the center of this was a collapsed strand of disintegrated cells where the embryo sac should have been. Since it is scarcely possible that the embryo sac cavity would collapse completely after anthesis if any fertilization had taken place, this is strong evidence that nearly perfect seed coats can be formed in Vitis without fertilization.

Since 16 Black Corinth seeds have been germinated and several have been found to have endosperm, it is obvious that occasionally a viable Black Corinth seed is formed. Microscopic examination disclosed one embryo sac which might have been normal. Perhaps, more frequently a normal fusion nucleus occurs which can be fertilized and develop endosperm even though the egg apparatus degenerates.

III.—Seed Abortion in Sultanina, Sultanina Rose, Sultanina Gigas, Sultana, and Monukka

A third major type of seedlessness characterizes the varieties Sultanina, Sultana, and Monukka. The Sultanina, cultivated under

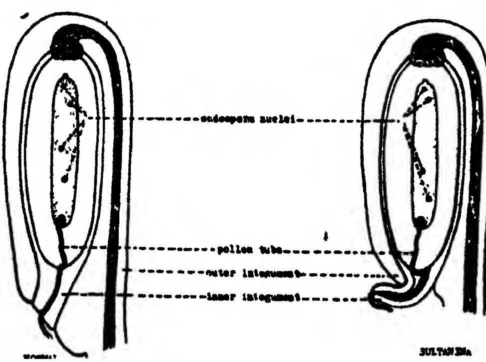

Fig. 3. Normal Vitis Ovule and Sultanina Ovule 3 Days after Anthesis.

the name of Thompson's Seedless in the United States, is one of the most important commercial varieties. The Sultana is of some commercial importance, and the Monukka has also obtained slight commercial favor.

The author finds that in practically every case, in Sultana and Monukka as well as Sultanina, abnormalities can be detected in the integuments at the time of anthesis. The inner integuments are frequently abnormally elongated so that their tubular tips are twisted or bent back along the sides of the ovules because of pressure against the ovary wall. The external integuments are as a rule abnormally short and the inner appear much exserted. In normal seeds, the tips of both integuments are very meristematic

and are packed rather tightly together, leaving only a very small micropyle, but in these seedless varieties the micropyle is usually very large and the tips of the integuments obviously less meristematic than in normal seeds.

In these varieties there is perhaps a larger number of abnormal embryo sacs than in normal-seeded varieties. Establishment of this as fact would take considerable statistical study since it is a common occurrence in seeded varieties for one or two, occasionally all four, of the ovules in an ovary to have no embryo sacs at the time of anthesis, or, less frequently, abnormal embryo sacs. However, there is a very high percentage of normal appearing embryo sacs and in nearly every ovary two or three embryo sacs have pollen tubes entering them within two or three days after anthesis.

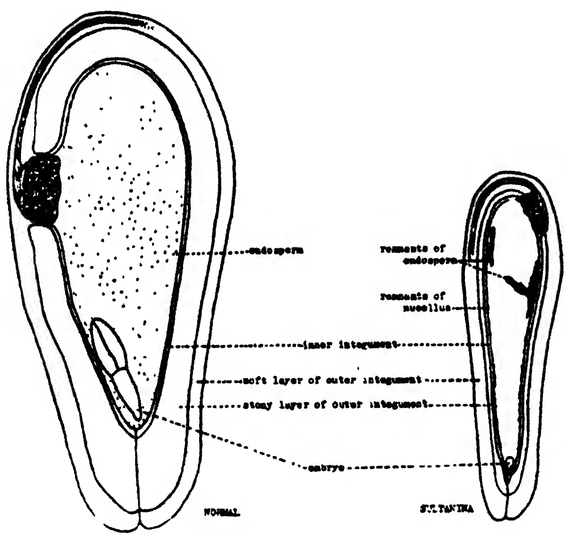

FIG. 4. Normal Vitis Seed and Unusually Well Developed Sultanina Seed. (Same Scale.)

The second important point which previous observers have missed is that in practically every embryo sac which has been entered by a pollen tube the endosperm nucleus starts a series of divisions. For this reason this type of development in Vitis should no longer be considered to illustrate stimulative parthenocarpy. The stimulus apparently comes, not from pollen tube growth, but rather from the usual process of endosperm fertilization, which starts this food storage tissue growing and drawing upon the assimilated materials of the vine.

In the normal Vitis seed (1) a complicated series of changes in the integumentary tissues begins immediately after fertilization, so that within 2 weeks the fossettes at the sides of the raphe have infolded and the chalaza has grown over into the dorsal region of the ovule.

The nucellar cells have enlarged tremendously and have also, for the time after fertilization, continued to increase somewhat in number. For at least 2, and probably 3 or 4, weeks after fertilization the zygote does not divide, but the endosperm nuclei continue dividing slowly. They do not, however, encroach much upon the nucellus until the seed has reached practically its full size.

In Sultanina, Sultana, and Monukka, the processes of seed coat formation break down in varying degrees. Because the middle layer of the external integument is not developing normally, the fossettes are only imperfectly formed. The upper part of the seed may not grow enough to displace the chalaza into the dorsal region where it is finally located in the normal seed. The internal epidermis of the external integument undergoes a fraction of the cell division which it does in the normal seed and the cell walls may be thickened. Thickening of these cell walls does not seem to take place in the hardest seeds of Sultanina as extensively as it does in the hardest seeds of Monukka and Sultana, whose seeds may become considerably more stony than those of Sultanina. Because of feeble development of the external integument the beak of the seed has a characteristic long, thin appearance in all three varieties.

In spite of the very abnormal seed development, embryos were found in three of 10 seeds of Sultanina (which were, however, examined because they were exceptionally large) which the author sectioned. In one Monukka seed, there was a well developed endosperm. Ross reported in 1875 that he had succeeded in getting four Monukka seeds to germinate and grow. Oinoue has succeeded in getting three Sultanina seedlings to grow.

Ringing, commonly practiced to increase the size of the Sultanina berry, was found to increase the sizes of the rudimentary seeds also.

The author has emasculated at least a dozen Sultanina clusters and has never got any berries to set. In Monukka, however, two shoots which had been ringed were chosen for emasculation. They set perfectly. Nearly all of the berries had some seed coat development and even, in many cases, stony tissue, but most of the seeds were only a fraction of the size of the seeds on the pollinated clusters on ringed shoots. The berries of both clusters were strikingly round in contrast with the ordinary elongated Monukka berries. This bears out Muller-Thorgau's statement (2) that berry elongation in many varieties depends on fertilization.

Ringing during bloom can cause a very compact cluster of berries to set in Sultanina Gigas, while without ringing the clusters are very straggly. Since the pollen and embryo sacs of this tetraploid cannot be affected by ringing at this time, it must be that the heavy set is due to increased vegetative parthenocarpy. It is possible that the sterility due to abnormal chromosome numbers can be used in the development of commercially valuable seedless varieties.

All of the above described varieties, except the tetraploid Sultanina Gigas, have plenty of normal pollen for self-pollination.

Fruit development in seedless varieties of the unisexual eastern grapes may be due to vegetative parthenocarpy, coupled with absence of pollen. A seedless variety from Canada has no ovule development beyond bloom and yet has berries weighing 2 to 2.5 g. This proves that a good commercial size can be obtained without any seed development and encourages breeding work with vegetatively parthenocarpic varieties. However, the vegetatively parthenocarpic shot berries of Hunisa, one of the largest-berried Vinifera varieties, are very small.

Crosses involving the Sultanina type of seedlessness give recovery of the seedless type so frequently that we can expect it to be based on comparatively few genetic factors. This will make it easy to use in breeding for improved seedless varieties, unless there is trouble with the seed coats developing too much stony tissue. It is more promising than the vegetatively parthenocarpic varieties in breeding for size, since development in seed coats is correlated with development in size of berry.

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Orchard Soil Moisture Under Different Fertility Experiments[1]

By William S. Clarke, Jr., *Pennsylvania State College, State College, Pa.*

At State College, studies on soil moisture in the orchard have been in progress for the past 4 years. These orchards contain many different fertility conditions, such as, legume and fertilized non-legume sods; and cultivation with cover crops, both with and without commercial fertilizers. In these 4 years there have been prolonged droughts and also periods of excessive rainfall. The droughts have greatly accentuated the moisture problem in these orchards.

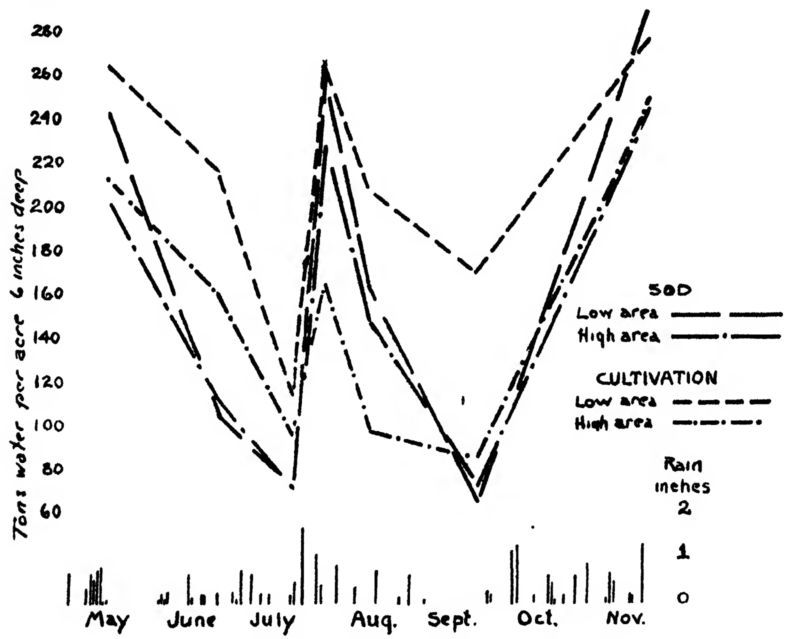

Fig. 1. Effect of slope on soil moisture 1932.

The soil is of limestone derivation, being largely a Hagerstown silt loam. The subsoil is mostly a heavy clay. The underlying rock is variable in depth, in places outcropping at the surface, and at other places being many feet below the surface of the ground. In general, it is deeper than 3 feet. The structure of the soil is good, drainage is excellent and there is no permanent water table.

In studying soil moisture, one must take into account the slope of

[1]Publication authorized by the Director of the Pennsylvania Agricultural Experiment Station April 26, 1933, as Technical Paper No. 589.

the land. Even where there is a gentle slope, there may be much more moisture in the soil at the bottom than at the top of the slope. Fig. 1 shows the tons of water per acre in the upper 6 inches of soil through four plots, two in sod and two in cultivation with cover crops, from May through November of 1932. The dot and dash lines represent the soil water at the upper edge of a gentle slope, and the evenly broken lines represent the soil water at the bottom of this slope 200 feet distant and about 5 feet lower in contour. The short broken lines represent cultivation with cover crops; the long broken ones represent sod. Rainfall is indicated at the base of the chart.

TABLE I—THE GAIN OF A SOIL UNDER A GOOD TREATMENT COMPARED WITH THE SOIL OF A CONTRASTED POOR TREATMENT IN MAXIMUM WATER CONTENT IN THE SPRING AND IN THE AMOUNT OF COVER CROP TURNED UNDER

Good Treatment	Poor Treatment	Tons Water per Acre 6 Inches at maximum in Spring 1930,	1931,	1932	Tons Cover Crop per Acre 1930,	1931,	1932
Sod 24 years, broken twice		300	280	260	3.24	—*	—*
	Clean cultivation12 years, sod 12, broken once	243	270	223	2.76	—	—
	Gain:	57	10	37	0.48	—	—
Fertilized sod 18 years, unfertilized cover 6 years		266	273	246	3.05	6.58	2.36
	Unfertilized cover 24 years	224	225	209	1.55	2.43	2.45
	Gain:	42	48	35	1.50	4.15	—.09
Cover fertilized with NP fertilizers 24 yrs.		230	223	216	1.42	3.15	4.76
	Unfertilized cover 24 years	207	221	210	.64	1.15	.98
	Gain:	23	2	6	.78	2.00	3.78
Cover fertilized with N 24 years		240	247	231	1.73	3.31	4.69
	Unfertilized cover 24 years	232	232	191	.63	1.63	2.44
	Gain:	8	15	40	1.10	1.68	2.25
Cover fertilized with manure 20 years		208	240	222	—*	7.07	—*
	Unfertilized cover 20 years	186	196	175	—	2.87	—
Both in fertilized sod 4 years, broken once	Gain:	22	44	47	—	4.20	—

*This plot was in sod in the year indicated, and no record of its cover was taken.

Following substantial rains, the lower parts of all plots contained more moisture in the first 6 inches of soil than the upper parts. Even in times of drought, the lower parts of the cultivated plots contained

more water than the upper parts, but the sod plots were equally dry all over. This situation may be ascribed, at least partially, to washing. Even though there is a heavy cover on the cultivated plots in the latter part of the summer, the bare and nearly bare areas allow of considerable washing during May and June. After heavy rains a small gully often develops in the cultivated plots. Therefore, in making comparisons of soil water among different plots, the investigator must take into account the differences due to contour.

Another important factor is the amount of organic matter turned into the soil. This is particularly true in the spring, when the soil water is at its maximum. (Table I).

In the first two columns of Table I are listed five contrasted plot treatments. These plots are side by side and with negligible differences in contour. They represent wide differences in fertility brought about by many years of differential treatments. The third column shows the water content in the upper 6 inches of the soils of these plots when at its maximum in the spring, 1930 to 1932. The fourth column gives the weights per acre of the cover crops grown on these plots. On the sod plots, covers were grown only in the years when they were torn up. These figures are averages of the weights of cover crops cut from three or more representative square yard areas in each plot.

In all cases the plots of better fertility contained more water in the spring. These figures may be more significant if one realizes that 1 ton of water means 240 gallons, and all the water mentioned here is confined to the upper 6 inches of an acre. In all cases but one, the plots containing more moisture in the spring grew considerably more cover crop during the summer. These cover crops were later plowed into the soil. Thus is established a cycle, that is, where more organic matter is turned under, the soil holds more moisture in the spring; this extra moisture aids in the growth of more cover crop to be turned under, and so on.

These two factors, slope and the amount of organic matter turned under, are important in considering how much water comes into the soil. Most of this soil water is lost during the summer through the use of plants. Fig. 2 shows the records through the summer of 1932 of four plots in an orchard adjoining those discussed in Table I, two under cultivation with cover crops, one a non-legume and the other a legume; and two under sod, one of fertilized blue grass with some other grasses, and one of alfalfa with some grass. These four plots are shown for this 1 year because their records are typical of the results for 4 years of investigations on many different plots.

The rainfall through the winter and spring of 1932 was normal. A fairly dry period early in the summer was followed by excessive rains, then by a prolonged drought the latter part of the summer, and then by a rainy fall. The trees are only 6 years old and are not yet a serious drain on the soil moisture. The records given here have been taken so as to avoid the differences due to contour.

The soil treatments have differed for only 2 years. For this reason the soils in the four plots are of equal fertility and have approximately the same initial water content in the spring. The sods, being already established, made a heavy draft on the soil moisture early in the season, the blue grass making an earlier heavy draft than the alfalfa. During June the cover crops, which were planted the latter part of May, made little demand. This early draft on soil water at the same time when the trees are also making most of their growth and setting their fruit buds may be one of the factors in the frequent unfruitfulness of sod orchards.

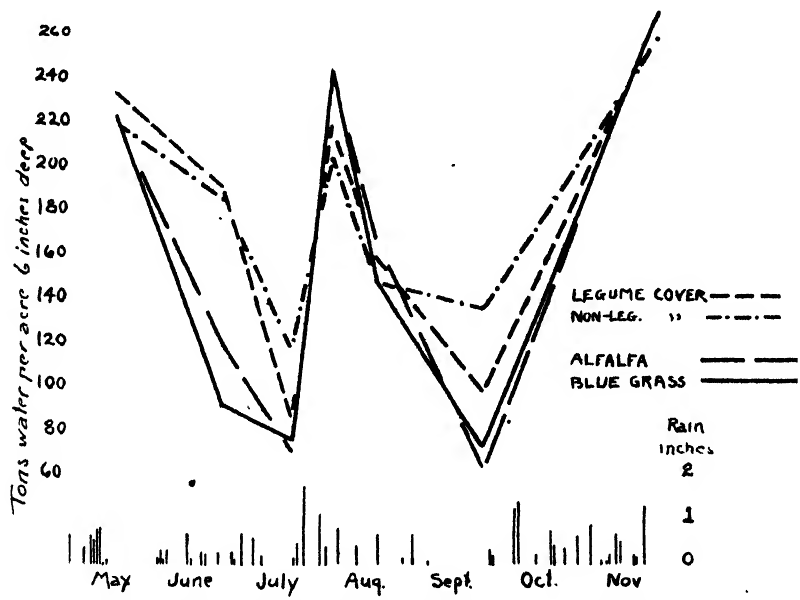

FIG. 2. Soil moisture under different cultural treatments 1932.

The sods were mowed on June 22. The blue grass was mature and made little further growth during July. It had already used most of the available soil water in the upper 6 inches. The alfalfa made a second growth and used up most of the remaining available moisture in its upper 6 inches. The cover crops were now growing well, and they rapidly depleted the water. The legume cover of mixed clovers, including sweet clover, started more quickly than the non-legume cover of millet, and it also used water more rapidly.

Toward the end of July there was a period of heavy rains, and the water content of all plots was raised nearly to the spring level. The sod plots showed slightly greater ability to absorb moisture than the cultivated ones. There was also some washing in the cultivated plots. Following these rains, it was rather dry until the last of September. In spite of the fact that the sods were mowed again in the middle of

August, they continued their growth and again used more moisture than the cover crop plots. The millet cover crop was also cut in the middle of August, and it was later turned under. With no growing cover, this plot maintained its soil water at practically the same level, in spite of prolonged drought and a period of extreme heat. These facts suggest that, in spite of drought, the cutting of the cover crop or the checking of sods will help to conserve moisture.

In both October and November the rainfall was above normal, totaling nearly 9 inches. All plots were well supplied with moisture, and each had about the same water content as in the spring.

This study was made on the surface soil. Studies are now being made on subsoil moisture, and they will be reported later.

It is concluded from this study that the following factors must be considered, namely, (1) slope and washing, the latter especially on cultivated plots; (2) the content of organic matter; and (3) the utilization of soil moisture by different covers.

Preliminary Report of Pear Tree Responses to Variations in Available Soil Moisture in Clay Adobe Soil

By W. W. ALDRICH and ARCH WORK, *U. S. Department of Agriculture, Washington, D. C.*

A THOROUGH study of the responses of pear trees in the Rogue River Valley of Oregon to soil moisture was started by the U. S. Department of Agriculture and the Oregon Experiment Station in 1930. Data obtained in the course of this investigation during the past year seems sufficiently definite and important to warrant a brief report at this time.

These results were obtained in a 3-acre block of 15-year-old Anjou pear trees at the Medford Experiment Station. These trees suffered slightly from lack of soil moisture during the summer of 1931. They received 2½ pounds of ammonium sulfate per tree in the fall of 1931 and were pruned heavily during the winter of 1931–2. In the spring of 1932, when these experiments were started, the trees bloomed heavily, but after the June drop only a moderate crop (about 40 leaves per fruit) remained. The soil is classified (5) as Meyer clay adobe. A typical sample of this soil has the following mechanical analysis expressed in per cent:

Fine Gravel	Coarse Sand	Medium Sand	Fine Sand	Verv Fine Sand	Silt	Clay
1.3	3.1	3.3	6.4	6.3	27.6	51.8

This soil is typical of about 50 per cent of the pear orchard soils in the Valley.

The block was divided into four plots, each four to five trees wide and six trees long, with two guard rows between plots. The designations of the plots and the times of application of each irrigation are:

Plots	Dates of Irrigation						
One Irrigation	—	—	—	—	—	Aug. 12	—
Frequent Early	Apr. 18	May 19	June 18	July 9	—	—	—
Frequent Late	—	—	—	—	July 22	Aug. 12	Aug. 27
Frequent	Apr. 18	May 19	June 18	July 9	July 22	Aug. 12	Aug. 27

The trees in the One Irrigation and Frequent Early plots carried slightly less fruit after the June drop than the trees in Frequent and Frequent Late plots.

At each irrigation a measured quantity of water, sufficient to wet

the entire soil mass (above the bedrock) to field capacity, was applied. Uniform distribution of water over the surface was secured by using seven furrows spaced 3 feet apart in each 25-foot middle. The slope of the furrows was 1 foot per 100. The soil averaged 4 feet deep in the One Irrigation and Frequent Early plots and 5 feet deep in the Frequent Late and Frequent plots. The water-table stood below the top of partially disintegrated shale bedrock.

Soil samples for moisture determinations were taken at 1-foot increments from the bottom of the mulch to the bedrock. Locations for sampling were fixed at distances of 4, 7.5, 10, 11.5, and 13 feet from the trees. Each of these locations was quadruplicated, making a total of twenty sampling points in each plot. Throughout the season all samples were taken from a small area surrounding each location.

The field capacity was determined for each of the upper 3 feet in each plot by averaging the three highest plot averages of soil moisture found during the spring and summer. The wilting point (used synonymously with "permanent wilting percentage") of the soil of each foot in each plot was determined by growing sunflowers in sealed cans. From 30 to 80 determinations were made for each foot. The difference between the field capacity and the wilting point is considered the maximum available moisture. Since neither the field capacity nor the wilting point were the same for all the plots, the soil moisture present above the wilting point was calculated and expressed as per cent of maximum available moisture.

Tree response data are based upon the average of six observation trees in each plot. Fruit growth was determined by semiweekly measurements of the circumference of 15 tagged fruits per tree and calculation of the volume, assuming the fruits to be perfect spheres. The stomatal behavior was followed by the method of Magness and Furr (4), with the results expressed in hours per day that 40 per cent of the stomata showed any opening. To determine shoot diameter, 20 lateral shoots per tree were calipered midway between the fourth and fifth leaves from the distal end. Shoot length was measured on 100 lateral shoots per tree. The average increase in trunk circumference for the period, March 29 to October 31, was based upon 14 to 17 trees rather than upon six trees per plot. The probable error of each average was calculated by Bessel's formula.

Results

Study of root distribution, to be reported elsewhere, shows that the root concentration in the top 6 inches of soil is relatively small, and that the principal root mass is located in the upper three feet of soil whose moisture variations are reported.

During the period from May 22 to July 22 the available soil moisture (see Fig. 1) was consistently lower in the One Irrigation than

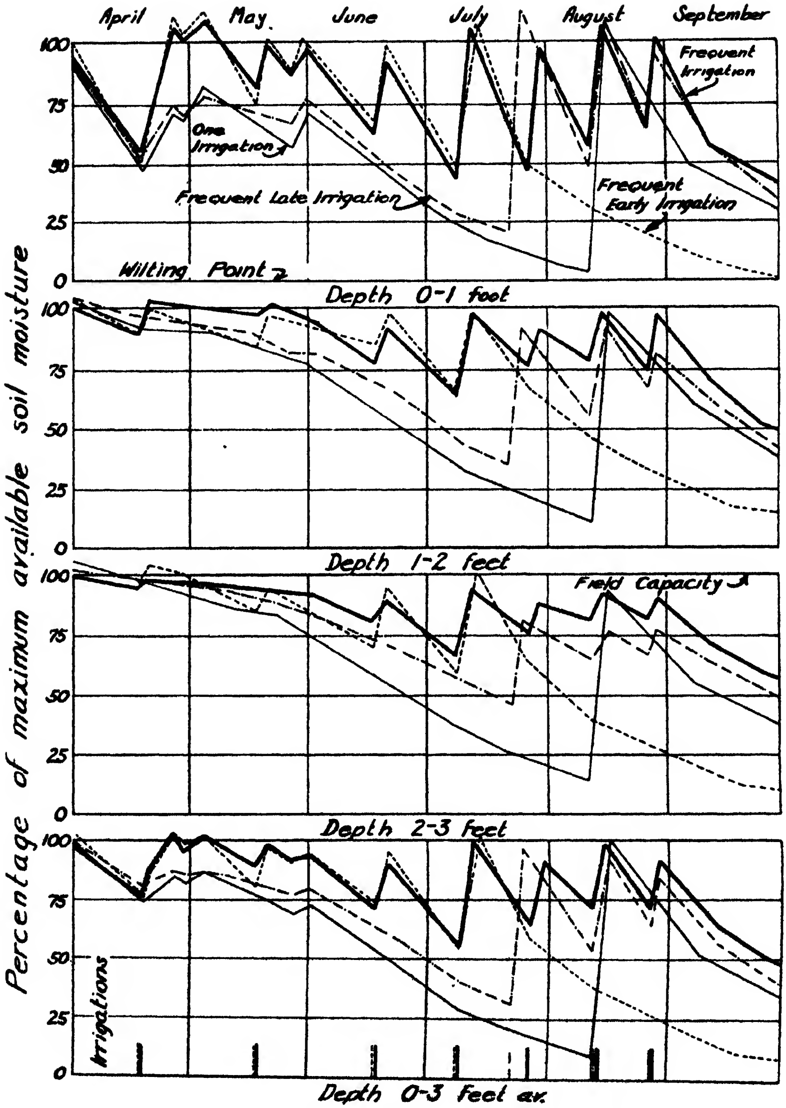

FIG. 1. Variations in soil moisture, expressed as per cent of maximum available moisture, in the 0–1, 1–2 and 2–3 foot depths, together with average of the entire 0–3 foot zone, for the four plots

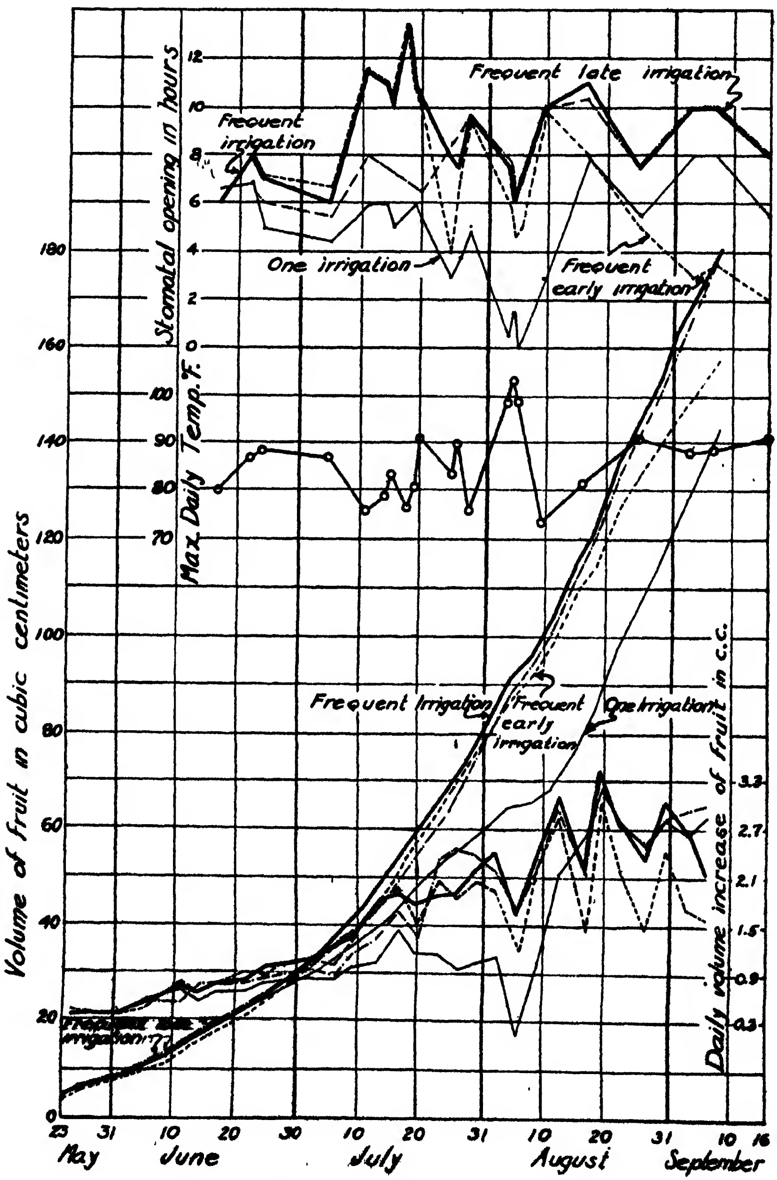

FIG. 2. Fruit volume increase and duration of daily stomatal opening for the four plots, together with the maximum air temperature on days when the stomata were observed.

in the Frequent Late plot though neither had received irrigation. This was probably on account of the 1 foot shallower soil in the former plot, providing a smaller soil moisture reservoir, and the resultant more rapid reduction of soil moisture by the trees from each unit volume of soil. Although during this period the soil moisture was not reduced to the wilting point, the fruit growth (see Fig. 2) from June 20 to July 22 was slower in the One Irrigation than in the Frequent Late plot. Statistical analysis (see Table I) of the increases in fruit volume shows this difference to be significant as early as June 27. During this period, June 20 to July 22, the daily duration of stomatal opening (see Fig. 2) was slightly less in the One Irrigation than in the Frequent Late plot. Lateral shoot growth in length (completed by July 10) and growth in diameter (completed by August 11) were also less (see Table II) in the One Irrigation than in the Frequent Late plot.

TABLE I—AVERAGE INCREASE OF FRUIT VOLUME, WITH PROBABLE ERROR OF AVERAGE FOR EACH PLOT DURING CRITICAL PERIODS (IN CC)

Treatment	June 20 to 23	June 23 to 27	July 28 to August 1
One irrigation	2.4±.05	2.9±.08	4.2±.08
Frequent late	2.4±.05	3.4±.06	8.8±.11
Frequent	2.6±.04	3.9±.08	8.7±.14
Frequent early	2.6±.04	3.6±.07	8.0±.13

TABLE II—AVERAGE SHOOT DIAMETER, SHOOT LENGTH AND TRUNK CIRCUMFERENCE INCREASE, WITH PROBABLE ERROR, FOR ALL PLOTS

Treatment	Shoot Diameter on August 11 (Cm)	Shoot Length on October 31 (Cm)	Trunk Circumference Increase (3/29–10–31) (Cm)
One Irrigation	3.25±.02	29.1±.33	1.8±.08
Frequent early	3.90±.05	39.1±.52	2.2±.09
Frequent late	3.49±.02	37.4±.44	2.3±.08
Frequent	4.25±.03	36.5±.54	2.5±.08

During the period, May 22 to July 22, the soil moisture in both the One Irrigation and the Frequent Late plots was not reduced to the wilting point but was lower than in the Frequent and Frequent Early plots. The fruit growth and duration of stomatal opening was also less in these drier plots from June 20 to July 22. When the first significant difference in rate of fruit growth occurred on June 23, approximately 50 per cent of the maximum available moisture in these drier plots was still present. Shoot growth in diameter, most of which occurred during this period, was significantly less for the One Irrigation and Frequent Late plots than for either the Frequent or Frequent Early plots. Following irrigation of the Frequent Late plot on July 22 the rate of fruit growth and duration of stomatal opening increased.

After July 24 the soil moisture in the Frequent Early was lower than in the Frequent or Frequent Late plots, but at no time did the soil in any of these plots lack available moisture in the upper 3

feet. After July 28 the rate of fruit growth in the Frequent Early plot was slower than in the other two plots, with this difference significant by August 1. After July 25 the period of daily stomatal opening for this plot also was less, on nearly every day of examination, than for the other two plots. Shoot growth in diameter (completed by August 11) was significantly less in the Frequent Early than in the Frequent plot, indicating the effect of the soil moisture difference between July 24 and August 11. The slightly greater shoot growth in length (barely significant) in the Frequent Early than in the Frequent plot can only be attributed to the slightly smaller crop in the former plot.

The One Irrigation plot was lower in available soil moisture than the other three until August 12, although the 1 to 3 foot depth always contained available moisture. The 0 to 1 foot depth approached the wilting point during the first 12 days of August. At no time did the trees show signs of wilting, even during 3 days when the maxmium temperatures were between 98 and 103 degrees F. Fruit growth, which nearly ceased in this plot during this hot period, continued again during the cooler period preceding the irrigation on August 12. Stomatal opening was less preceding August 12 than in the other three plots. On the very hot days of August 3, 4, and 5, stomata were observed open only during the relatively cool period at sunrise. Following the irrigation on August 12 the rate of fruit growth and the period of stomatal opening were increased. However, the daily duration of stomatal opening was not as great subsequent to August 12 as in the Frequent and Frequent Late plots, having approximately the same amounts of soil moisture. Trunk growth, and shoot growth in diameter and in length were significantly less than in the other three plots.

Discussion

The rate of fruit growth was particularly sensitive to differences in available soil moisture. Fruit growth was significantly decreased when the soil contained about 50 per cent of the maximum available moisture in the upper 3 feet, as compared to that in other plots having greater amounts of available moisture. Thus in Meyer clay adobe soil, containing about 50 per cent clay, the fruit growth was affected by differences in soil moisture well above the wilting point. A similar effect to a less degree was observed by Furr and Degman (1) studying apples in shaly loam soil. However, Hendrickson and Veihmeyer working with peaches (2) in Madera and Gridley loam and in Fresno sandy loam, and with grapes (3) in Fresno sandy loam, concluded that the fruit was not affected until the soil moisture was reduced to "about the permanent wilting percentage."

The differences in daily duration of stomatal opening between the plots correlated with differences in available soil moisture well

above the wilting point. Such a relation was indicated by the work of Furr and Degman (1).

The smaller growth in diameter of the lateral shoots of the Frequent Late and Frequent Early as compared with the Frequent plot apparently was due to differences in available soil moisture well above the wilting point. The shoots of the One Irrigation plot made less growth both in length and in diameter, and the trunk circumference increased less than in any other plot though the second and third feet of soil were well above the wilting point. These growth responses are not in agreement with the results of Veihmeyer (6), obtained on lighter soil, who concluded that peaches and prunes were not influenced by differences in amount of water above the wilting percentage.

Since in all probability the trees in all plots initially had, on the average, similar root systems and water conducting tissues, the differences in tree responses were due in large measure to variations in the availability of soil moisture. It is possible, however, that less twig and trunk growth, following reductions in available soil moisture, may have subsequently reduced the water movement in the trees of those plots, and therefore may have accentuated the soil moisture deficiency in such trees. Since the results obtained in this clay adobe soil are more pronounced than those found by Furr and Degman (1) in a lighter soil and are contrary to other results on still lighter soils, it would seem that these tree responses to variations in available soil moisture resulted from differences in rate of water movement to the roots. Apparently, in such heavy soil, moisture did not always move to the roots as rapidly as the water was utilized by the trees; so that when there was less available soil moisture in one plot than in another, the water taken up by the tree was less in the former case than in the latter.

Conclusions

In the heavy soil type in which these experiments were conducted apparently a moisture supply representing approximately 50 per cent of the maximum available moisture, or over, was essential for maximum growth of fruit, shoots and trunk.

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Soil Acidity and Orchard Production

By JOSEPH OSKAMP and L. P. BATJER, *Cornell University, Ithaca, N. Y.*

IN a study of soils in relation to fruit growing in New York, a number of samples of soil were available from orchards of known performance growing on soils with definitely determined profile characteristics.[1] In certain areas there appeared to be a relationship between the acidity of the surface soil, the soil type, and the production of Baldwin apple trees; a medium to strongly acid soil being more often associated with high production than one slightly acid to neutral.

The pH was determined electrometrically for the surface soils at 49 Baldwin and 49 R. I. Greening apple trees in one orchard at Hall, Ontario County, and for the surface soils in 58 orchards in the Hilton, Morton areas, Monroe County.

The samples were taken with a soil auger, and represent a core of earth through the surface layer. Loose soil, grass or other surface debris was removed and all the soil drawn up by the auger to within 1 inch of the next zone of the profile was used. Each sample is a composite of 3 such borings, made about equi-distant around a tree at the edge of the branches.

The data in Table I and the graph in Fig. 1 show that there is a general tendency for tree yields to increase as the soil acidity at the tree location increases. When yields are correlated with pH value coefficient of correlation is —.410, ± .0818. However, the Rhode Island Greening trees in the same orchard show no such relationship, the coefficient of correlation being —.1755, ± .0953 (Fig. 2).

The data for the 58 Baldwin orchards reported in Table II show a similar trend to the 49 individual Baldwin trees; although when orchard yields are correlated with pH the coefficient of correlation is slightly less being —.312, ± .0822.

It is not thought that the response of the Baldwin trees is the direct result of soil acidity, but an indirect effect, probably one of drainage. (This may also be the reason why the R. I. Greening trees do not respond within the pH range here measured as observa-

[1]This is one phase of an investigation into the relation of soil to fruit growing which is part of the larger state program of land utilization, the study of which has been entrusted to the New York State College of Agriculture at Cornell University. The following publications contributed by the Department of Pomology have gone to press:

1. Soils in relation to fruit growing in New York, Part I, A detailed soil survey of the Hilton area, Monroe County, by A. T. Sweet and Joseph Oskamp, Cornell Univ. Agr. Exp. Sta. Bul. 541. 1932.

2. Soils in relation to fruit growing in New York, Part II, The size, production and rooting habit of apple trees on different soil types in the Hilton-Morton areas, Monroe County, by Joseph Oskamp and L. P. Batjer, Cornell University Agr. Exp. Sta. Bul. 550. 1932.

TABLE I—SOIL ACIDITY AND YIELD OF 35-YEAR-OLD BALDWIN AND R. I. GREENING APPLE TREES IN A SINGLE ORCHARD AT HALL (ARRANGED IN ORDER OF ASCENDING YIELD INDEX)

Baldwin			R. I. Greening		
Tree No.	Yield Index*	pH†	Tree No.	Yield Index*	pH†
1 XII-15	44	7.14	1 XI-24	54	7.59
2 XII- 4	45	7.09	2 XVII-16	56	6.25
3 XII- 3	56	7.01	3 XVII- 1	57	6.33
4 XII-24	60	7.76	4 XVII- 4	57	7.45
5 XII-18	61	7.45	5 XVII-25	61	6.72
6 XII- 9	66	7.31	6 XVII- 2	68	6.49
7 XII- 1	68	7.62	7 XI- 9	73	6.89
8 XII- 7	70	6.87	8 XI-4	75	6.57
9 XII-25	71	6.92	9 XI-2	79	6.22
10 XII- 5	73	6.76	10 XVII-28	79	6.82
11 XII-17	75	7.22	11 XVII-19	83	6.46
12 XII-20	78	6.45	12 XVII-27	84	6.52
13 XII-16	85	6.56	13 XVII-29	84	7.38
14 VI-12	86	6.40	14 XVII-12	84	6.21
15 XII-23	86	7.10	15 XVII-17	86	5.88
16 VIII-6	90	5.99	16 XVII- 3	87	6.86
17 XII-21	91	6.76	17 XI-21	88	6.91
18 XII-13	92	7.39	18 XVII-13	90	6.00
19 XII-19	93	7.25	19 XVII-23	90	6.68
20 XII-22	93	6.89	20 XVII-8	91	5.84
21 VIII-10	94	5.96	21 XVII-9	91	6.02
22 VI-1	95	7.29	22 XI-16	93	6.60
23 VI-6	98	7.15	23 XVII-7	96	6.61
24 VI-9	98	6.85	24 XVII-24	99	7.24
25 VI-17	100	6.20	25 XVII-10	99	6.23
26 VIII-14	100	6.05	26 XI-10	100	6.97
27 VIII-11	106	6.52	27 XI- 7	102	7.05
28 VIII-13	107	6.46	28 XVII-30	103	6.41
29 VIII- 3	107	5.68	29 XI-17	104	6.53
30 VIII- 7	108	6.16	30 XI-19	104	6.56
31 VI-14	110	6.56	31 XI-23	105	7.25
32 VIII- 5	112	5.40	32 XI-1	106	7.37
33 VIII- 4	112	7.20	33 XI-5	107	7.27
34 VI-7	115	7.17	34 XVII-22	114	6.74
35 VI-5	118	6.93	35 XI-15	116	6.76
36 VI-16	121	6.81	36 XI-3	118	6.37
37 VIII-17	121	6.46	37 XI-11	119	7.03
38 VI-8	123	6.54	38 XVII-31	120	6.82
39 VI-18	124	6.75	39 XVII-6	122	6.72
40 VI-2	124	7.26	40 XI-13	122	6.19
41 VI-11	124	6.38	41 XI-14	123	6.40
42 VI-4	129	6.45	42 XI-12	123	6.73
43 VIII-12	130	6.34	43 XVII-5	124	6.56
44 VI-13	132	5.87	44 XI-6	129	6.96
45 VIII-8	136	5.64	45 XI-18	129	6.15
46 VIII-16	137	5.80	46 XVII-20	136	6.61
47 VI-3	143	7.12	47 XVII-15	146	5.43
48 VI-15	147	6.88	48 XI-8	160	6.72
49 VI-10	150	6.49	49 XVII-14	162	6.14

*Yield index for 10-year period, based on the average yield of population equals 100.
†Each sample is a composite of three borings representing a cross section of the surface layer. Determinations made electrometrically with quinhydrone electrode, diluting 10 grams of field moist soil with 30 cc distilled water.

tion indicates that this variety is somewhat more tolerant to slow drainage conditions than Baldwin). The orchards studied have a rather level topography so that there is not a large surface run-off and much water must escape through percolation downward. If there is a heavy layer obstructing this downward movement drainage is slowed up and there is a tendency for a less rapid leaching away of the basic elements, resulting in a higher pH value. Such a condition of slow drainage may adversely affect orchards.[3] Thus

TABLE II—SOIL TYPE, SOIL ACIDITY AND YIELD OF 58 BALDWIN APPLE ORCHARDS IN THE HILTON-MORTON AREAS (ARRANGED IN ORDER OF ASCENDING YIELD INDEX)

Farm No.	Soil Type No.*	Yield Index†	pH‡	Farm No.	Soil Type No.*	Yield Index†	pH‡
1 102- 9	50	16	5.67	30 580-14	14	92	5.81
2 424-13	12	16	6.45	31 520- 9	21	92	6.26
3 44-13	12	20	6.03	32 404-79	3	101	5.85
4 178-77	12	28	6.43	33 568-70	21	108	5.21
5 540-80	14	36	6.50	34 512- 9	21	108	5.92
6 244- 7	12	36	6.15	35 512-69	22	108	5.97
7 88-14	17	40	5.99	36 500-79	3	108	5.30
8 168-84	14	41	6.56	37 536-80	22	111	6.23
9 188-80	12	41	6.26	38 52-11	50	112	5.45
10 140-69	17	42	6.52	39 530-14	22	120	5.95
11 82-76	18	44	6.50	40 146-85	52	120	5.83
12 15-12	22	48	5.35	41 156-10	21	124	6.04
13 564-12	14	52	5.97	42 204- 8	22	132	6.05
14 424-11	12	52	6.50	43 134-70	21	137	5.71
15 38- 5	12	52	6.04	44 66- 8	50	140	6.36
16 422-70	12	55	6.68	45 544-10	14	144	6.68
17 176-80	50	55	5.93	46 16-12	50	144	5.68
18 90-10	12	56	6.39	47 80-11	22	144	5.24
19 520-69	21	60	5.45	48 424-79	52	145	5.73
20 20-80	50	61	6.23	49 502-69	3	150	4.70
21 174-70	52	62	5.98	50 132-65	21	160	5.92
22 130-70	21	62	5.66	51 504-69	3	173	4.96
23 6- 9	21	68	6.09	52 4-11	22	176	5.91
24 194-81	12	72	5.77	53 524-10	3	176	5.50
25 144-70	22	80	5.62	54 574-75	21	215	5.57
26 80-72	22	80	5.95	55 204-85	22	219	5.58
27 530-70	17	87	6.91	56 510-9	21	220	5.24
28 554-80	21	90	6.00	57 524-69	3	251	5.50
29 164-84	50	91	5.26	58 552-7	22	264	5.82

*These soil types are more fully described in references cited in footnotes 1 and 2, briefly they [illegible] profile; loam texture with clay at 2 or 3 feet. No. 18, similar to 17 but silt to clay loam surface and glacial deposit usually at about 4 feet. The above types Nos. 3, 21, 22, 17, 18, are of water sorted material.

No. 52 slightly mottled profile; loam to sandy loam to depth of 3 feet where compact glacial material is reached. No. 50 similar to No. 52, but heavier in texture. No. 12 much mottled or gray layer profile; sandy to silt loam in texture, grading heavier with depth. No. 14 heavier and more extreme type than No. 12. Types Nos. 52, 50, 12, 14, are of unsorted glacial material.

†Yield index based on 3-year average yield for all orchards in 45 to 65 years age group taken as 100. Orchard yields furnished thru the courtesy of T. E. LaMont, Department of Agricultural Economics and Farm Management of the New York State College of Agriculture, Cornell University.

‡An average of two or more samples typical of the soil types predominating in the orchard; each sample being a composite of three borings representing a cross section of the surface layer. Determinations made electrometrically with quinhydrone electrode, diluting 10 grams of air dry soil with 80 cc distilled water.

[3]See footnote 1.

high pH values may be associated with low yields. That a neutral or slightly alkaline condition is directly harmful is equally doubtful in view of the extent to which apple tree roots have been found to penetrate calcereous horizons of the profile, derived from water sorted material.[8]

From studies made in other areas in New York State the results of which are not yet fully tabulated and ready for publication, it seems that either a negative or a positive correlation between soil

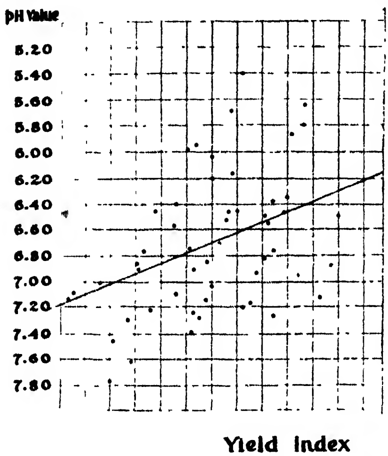

FIG. 1

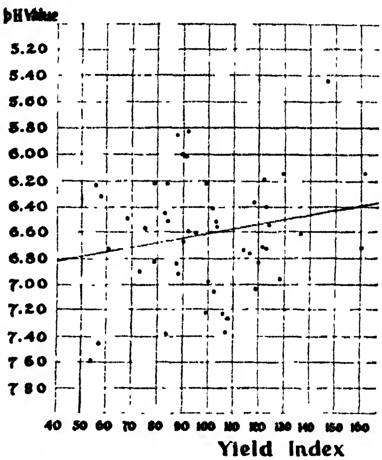

FIG. 2

FIG. 1. Relation of Soil Acidity to Yield of Baldwin Apple Trees in a Single Orchard.

Each dot is the record at an individual tree. The coefficient of correlation is —.410 ± .0818 and the correlation line indicates the trend; it is probably significant.

FIG. 2. Relation of Soil Acidity to Yield of R. I. Greening Apple Trees in a Single Orchard.

Each dot is the record at an individual tree. The coefficient of correlation is —.1755 ± .0953 and the correlation line indicates the trend; it is not significant.

acidity (within the limited range considered) and yield is not of general application, but confined to locations where certain sets of conditions prevail. The soil reaction is nevertheless of value, along with other factors, in helping to interpret the effect of soils on orchards.

Any study of the relationship between fruit trees and soil is not complete without a knowledge of the entire soil profile within the depth range of the roots. The pH of the surface soil has been used here, because in the areas considered it is an index of the reaction profile. This is shown in Table III which gives only a few of the many complete profiles examined.

TABLE III—CHARACTERISTIC REACTION PROFILE OF MAIN SOIL TYPES DISCUSSED

Area	Soil Type No.	Zone 1		Zone 2		Zone 3		Zone 4		Zone 5	
		Depth (Ins.)	pH	Depth (Ins.)	pH	Depth (Ins)	pH	Depth (Ins.)	pH	Depth (Ins.)	pH
Hilton, Morton	3	0–5	4.83	5–24	5.50	24–54	5.41	54–72	5.33	72–96	5.17
Hilton, Morton	21	0–8	5.25	8–11	5.25	11–30	5.33	30–48	8.38	48–102	8.38
Hilton, Morton	22	0–6	5.92	6–12	5.75	12–48	8.35	48–60	7.20		
Hilton, Morton	18	0–10	6.51	10–14	6.70	14–28	6.43	28–48	8.04		
Hilton, Morton	52	0–6	5.57	6–14	6.67	14–20	5.33	20–42	5.17	42–48	6.52
Hilton, Morton	12	0–6	6.64	6–12	6.60	12–34	7.38	34–48	8.21		
Hall	8–16*	0–6	5.80	6–9	6.60	9–18	7.53	18–42	8.38	42–48	8.55
Hall	12–4†	0–10	7.14	10–14	8.11	14–22	8.38	22–46	8.46	46–60	8.35

*Typical low pH profile.
†Typical high pH profile.

Effects of Leaf Area, Nitrate of Soda, and Soil Moisture on Fruit Bud Formation in the Delicious Apple

By C. P. Harley, M. P. Masure, and J. R. Magness, *U. S. Department of Agriculture, Washington, D. C.*

ABUNDANT evidence is found to the effect that carbohydrates are very important in the production of fruit buds in the apple. Recent reports by Magness (3), Magness and Overley (4), Haller and Magness (2), Aldrich (1), and others, emphasize the necessity of adequate leaf areas to maintain a sufficient carbohydrate reserve for fruit bud formation, over and above the heavy demands made by developing fruits. The application of these findings to orchard practices is apparent, although the question of interrelated factors might well be considered.

It is commonly believed that the heavy annual production of apples secured in many orchards in the Pacific Northwest may be attributed to the control of soil moisture through irrigation, and also, to the rather heavy applications of commercial fertilizer. The possibility of an interrelation of these factors in the formation of fruit buds was investigated during the summer of 1931 and spring of 1932.

Experimental Methods and Plot Treatments

The experimental orchard is located at Orondo, Washington. A block of 135 rather uniform 13-year-old Delicious trees was selected for study. They appeared to be vigorous, as interpreted by length of terminal growth, although the leaves were rather light green in color indicating that at the time they were somewhat deficient in nitrogen. No fertilizers had been applied for the 2 years prior to 1931. The soil consisted of 2 feet of clean cultivated light sandy loam with underlying coarse gravel. The plots, four in number, comprised full length rows of trees each separated from the others by a guard row. Plot 1, the check, included 28 trees and received no nitrate of soda treatments; plot 2, 15 trees, had 4.5 pounds of nitrate applied per tree May 27; plot 3, 16 trees, 4.5 pounds of nitrate May 27 and 4.5 pounds July 30; plot 4, 15 trees, 4.5 pounds of nitrate July 30 only. The nitrate was distributed in the irrigation ditches and watered in immediately. These plots were bisected by irrigation outlets. One-half of each plot was designated as "wet," or those trees which received frequent irrigations, so the soil moisture was maintained near the field capacity. The other half, designated as "dry," was irrigated only after the soil had reached the wilting percentage and the trees showed definite indications of wilting. The wilting percentage was reached in these "dry" plots July 4, July 24, and Sept. 1.

In order to study fruit bud formation under the varying conditions of soil moisture, nitrogen applications, and leaf area, branches

from trees in all plots were ringed, and thinned or defoliated to 10 leaves per apple, 30 leaves per apple, and 70 leaves per apple on June 1. Over 200 branches, which averaged from 1 to 1½ inches in diameter, bearing over 11,000 spurs, were selected for this ringing and thinning program. Records from this experiment were secured in the spring of 1932, when the blossoms started to open. A history of each type of spur and its performance during 1931 and the resulting performance in 1932 was recorded.

Results

As graphically shown in Fig. 1, marked differences in fruit bud formation were found to occur between spurs from branches ringed

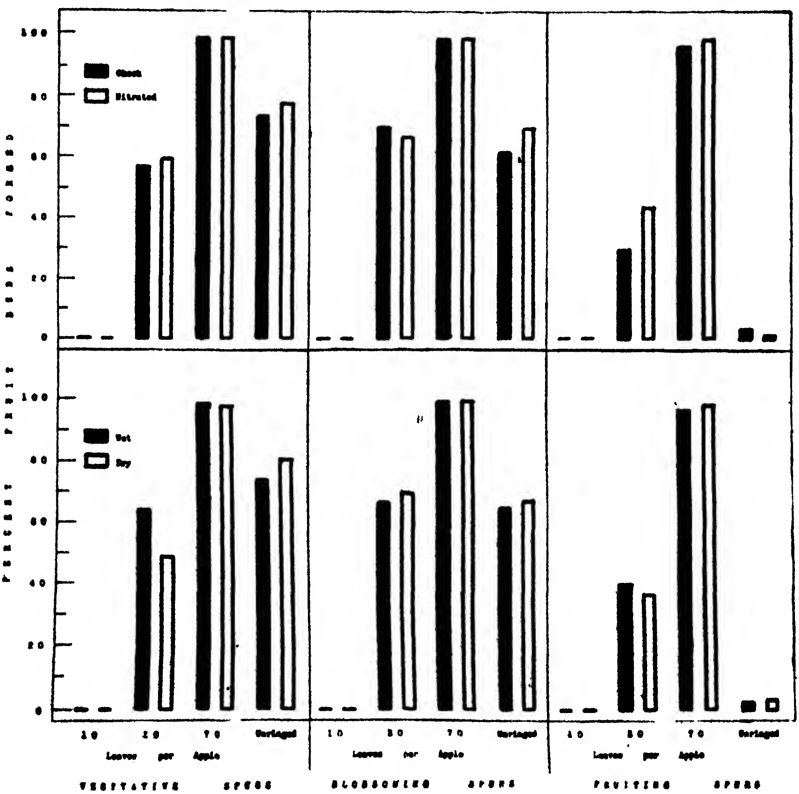

Fig. 1. Effect of leaf area, soil moisture, and nitrate of soda on percentage of fruit buds formed on three types of Delicious spurs. Branches ringed June 1, 1931.

June 1, due to the influence of 10, 30, and 70 leaves per apple. Spurs from branches with 10 leaves per apple failed to differentiate a single fruit bud regardless of spur type or soil treatment. With 70 leaves per apple practically 100 per cent of all spurs formed fruit

buds for the following year irrespective of type or soil treatment. In other words, under the influence of this excessive leaf area, practically all spurs, including those which matured fruits, blossomed again the following spring. With 30 leaves per apple an average of about 60 per cent of the vegetative and blossoming spurs set fruit buds, while in the fruiting spurs this percentage dropped to an average of about 37. At the beginning of the experiment it was estimated that the average ratio of leaves to fruits carried by the trees was about 30 leaves to each apple. Performance data from unringed branches indicate that vegetative and blossoming spurs functioned very similarly to those on ringed branches with 30 leaves per apple. However, while the branches which were ringed with 30 leaves per apple formed fruit buds on about 37 per cent of the fruiting spurs, on the unringed branches only about 3 per cent of the fruiting spurs formed fruit buds. This difference is probably due to a transport of carbohydrate materials from the unringed branches to the roots or other portions of the tree.

The upper three diagrams in Fig. 1 represent the percentage of fruit buds formed in the "check" and "nitrate" plots on three spur types and four conditions of leaf area. In the lower three diagrams the percentage of fruit buds formed in the "wet" and "dry" plots are contrasted. Data secured from the individual plots receiving the various nitrate of soda treatments were practically identical. This was also true of the different plots in the "wet" and "dry" portions of the orchard. For this reason data of all the nitrate plots were combined, as were also those in the "wet" and "dry" sections. As shown in Fig. 1, there was no uniform difference in the percentage of fruit buds formed either between the "check" and "nitrate" plots or between the "wet" and "dry" plots, with any of the leaf modifications used. It should be emphasized in this connection, however, that these dry plots did not remain in a dry condition for an appreciable length of time. With limited water-holding capacity in the soil, these trees reached the wilting percentage rather quickly, and as soon as this point was reached, water was applied. Similarly the non-nitrate trees were in excellent growth condition. Results might have been somewhat different had the period of water shortage been more prolonged, or had the non-nitrate trees been greatly reduced in growth condition by nitrogen shortage.

The behavior of spurs on unringed branches is of special significance. Conclusions drawn from the apparent lack of soil nitrogen effects on the development of fruit buds on ringed branches, might be subject to controversy. However, spurs from unringed portions of the tree responded in a similar manner to those from ringed branches, from the standpoint of nitrate and soil moisture influences.

Time of Fruit Bud Differentiation

Since the relation of leaf area and fruit bud formation may have an important application in maintaining annual production through fruit thinning practices, it would be advantageous to know the period during which this bud differentiation takes place or may be influenced. Experimental evidence has shown that early ringing

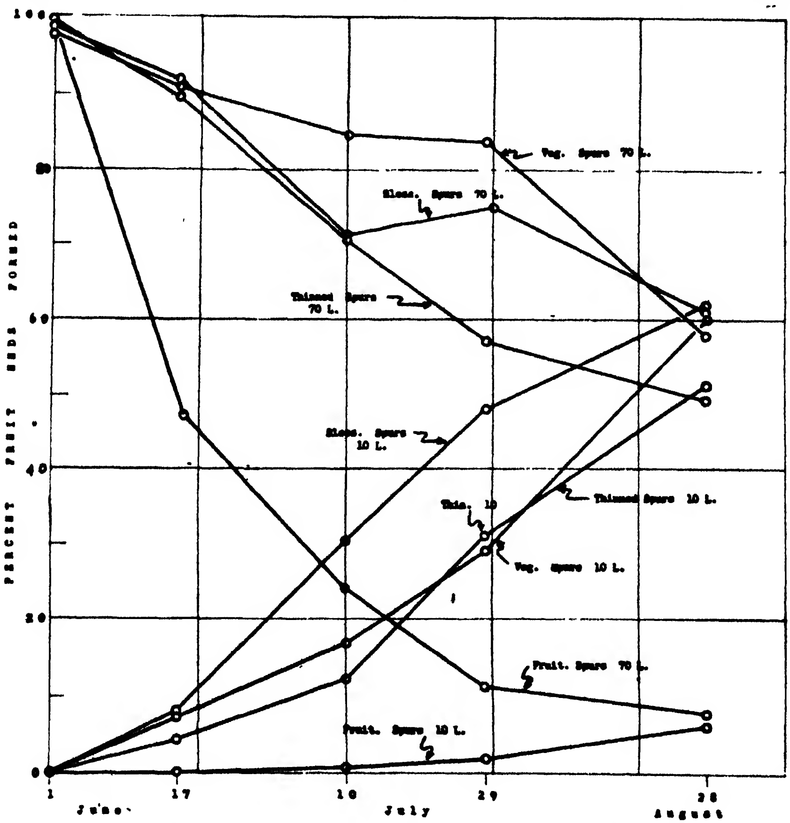

Fig. 2. Percentage of fruit buds formed from June 1 to Aug. 28 in four classes of Delicious spurs, under the influence of 70 leaves per apple and 10 leaves per apple, with periodic ringings. Dates of ringing June 1, June 17, July 10, July 29, and Aug. 28, 1931.

with 10 leaves or less per apple prevents fruit bud differentiation, while early ringing with 70 leaves or more per apple results in the formation of almost 100 per cent of fruit buds. Consequently it was planned to conduct a systematic series of ringing treatments. In one series the leaf area was adjusted to 10 leaves per apple with the thought that any fruit buds formed on these branches would have been initiated before the treatment was given. A parallel series having 70 leaves per apple was set up. This treatment would give

nearly 100 per cent fruit bud formation on the spurs if the buds could still be influenced to form fruit buds at the date the treatment was applied.

Sixteen branches were used for each leaf fruit ratio at each date. The dates of treatment were June 1, June 17, July 10, July 29, and August 28, 1931. Records taken in the spring of 1932 included the performance of four 1931 spur classes, namely, (1) vegetative spurs (non-bearing); (2) blossom spurs (did not set fruit); (3) thin spurs (fruit removed); (4) fruiting spurs (those which matured fruits).

The results of this study are presented in Fig. 2. In the June 1 ringing with 70 leaves per apple, practically all spurs of all classes set fruit buds, while in the 10-leaf per apple series no fruit buds were formed. In the series of branches ringed on June 17, fruit bud formation was down to approximately 90 per cent in the three classes of non-fruiting spurs and to about 47 per cent in the fruiting spurs, while the non-fruiting spurs ringed with 10 leaves per apple formed from 5 to 8 per cent of fruit buds. These data indicate that even by June 17 a small percentage of the spurs had passed beyond the stage where they could be influenced to form fruit buds as shown by the reduced fruit bud formation with 70 leaves per apple. On the other hand, a few spurs had apparently either definitely differentiated fruit buds by this date or were so near the point of differentiation that reducing the leaf area would not prevent fruit bud development.

The series of branches treated on July 29 still showed a marked difference between the 70-leaf series and the 10-leaf series in fruit bud formation, indicating that a considerable percentage of the buds could still be influenced either to form fruit buds or to fail to form fruit buds on that date. By August 28, however, the buds on the 10-leaf series and on the 70-leaf area were responding practically exactly alike. By this date all of the buds had apparently passed beyond the stage in which they could be influenced either to form or to fail to form flower parts.

These data suggest that the period during which fruit bud formation was occurring under the conditions of this test extended from around the middle of June until well into August but that fruit bud formation for the season was complete or could not be influenced by the end of that month. Apparently certain spurs are definitely differentiated either as fruit or leaf buds as early as June 17, while a few under the conditions of this test could be influenced well into the month of August. Similar data (not yet published) obtained on very much weaker Delicious trees in western Maryland indicate that on devitalized trees the period during which fruit bud formation may be influenced is much shorter.

Conclusions

Within the limits of the conditions of these experiments, soil moisture variations and nitrate of soda applications had no apparent direct effect on the time or extent of fruit bud formation in any of the spur classes. The principal factor in the initiation of fruit buds in the apple appears to be the ratio of the amount of foliage to fruit. Sufficient soil moisture and nitrogen, of course, are important in maintaining good growth conditions, but within the limits used in these tests they do not appear to directly affect fruit bud formation.

The time of bud differentiation in vigorous Delicious apple trees apparently extends over a rather long period during the summer. Evidence was obtained which indicated that buds had differentiated as early as June 17 and that some buds could be influenced as late as July 29, and was suggestive of a still earlier and later date for some spurs.

Thinning practices that establish a relatively high leaf-to-fruit ratio early in the season should assist materially in insuring annual production.

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Relation of Soil Moisture to Fruit Bud Formation in Apples

By E. S. DEGMAN, J. R. FURR, and J. R. MAGNESS, *U. S. Department of Agriculture, Washington, D. C.*

THE opinion is rather widely held by orchardists and investigators that allowing fruit trees to become dry during the period of fruit bud formation is likely to result in greater differentiation of buds than if ample moisture is present. Following the extreme drouth of 1930 in the Shenandoah-Cumberland Valley there was a fairly heavy bloom of both peaches and apples in the spring of 1931. This would indicate that conditions of severe moisture shortage through July were at least not unfavorable to fruit bud formation.

In connection with irrigation investigations in the Shenandoah-Cumberland Valley started in 1930, detailed records have been made of the amount of crop per tree and of the fruit bud formation in irrigated and non-irrigated plots. Certain of these data are presented for the light that they throw on the question of the influence of moisture supply on fruit bud formation in apples.

In the spring of 1930, plots for irrigation investigations were laid out in a fairly uniform block of Rome Beauty and Oldenburg trees near Hancock, Maryland. Most of these trees blossomed fairly heavily and set a good crop of fruit in that season.

TABLE I—EFFECT OF CROP AND SOIL MOISTURE SUPPLY OF 1930 ON THE PERCENTAGE OF BLOSSOMS PRODUCED IN 1931

Treatment	Rome Beauty		Oldenburg	
	No. of Fruits per 100 sq. cm. Cross Sectional Area of Trunk 1930	Percentage of Growing Points Flowering 1931	No. of Fruits per 100 sq. cm. Cross Sectional Area of Trunk 1930	Percentage of Growing Points Flowering 1931
Wet mulch...	445	15.0	309	36.6
Dry mulch...	253	29.2	235	40.6
Wet cultivated	538	22.4	304	31.0
Dry cultivated	383	29.9	328	40.9

Moisture shortage in the non-irrigated plots began to develop by the middle of June. Up until that time the trees had not suffered for water, so that the irrigated and non-irrigated trees were approximately similar in foliage and growth at the time of fruit bud initiation. From the middle of June extending throughout the month of July, the non-irrigated trees were suffering seriously due to moisture shortage. Fruit growth rate on these trees throughout the season has been recorded by Furr and Magness (1).

In the fall of 1930 the yield per tree averaged approximately twice as great on the irrigated plots as on the plots receiving only

natural rainfall. This was due in part to the greater number of fruits per tree on the irrigated plots but was mainly due to the greater size of the fruit on these trees.

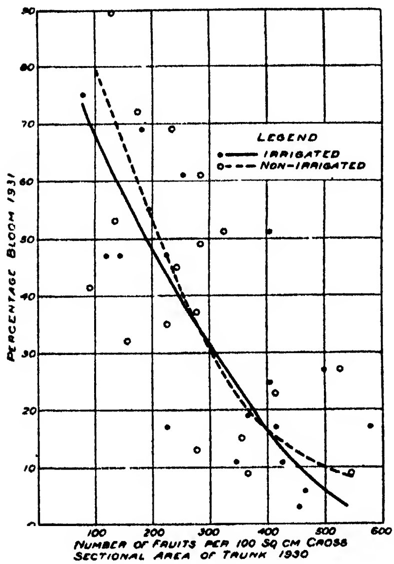

FIG. 1. Correlation curves showing relation of percentage bloom in 1931, to number of fruits produced in 1930, per 100 sq. cm. cross sectional area of trunk, on irrigated and non-irrigated Oldenburg apple trees.

Since there was some variation in the size of the individual trees, the crop per tree in 1930 has been calculated as the number of apple per 100 sq. cm. cross sectional area of the trunk. These data for 1930, together with the per cent of growing points flowering in the spring of 1931, are shown in Table I.

Data in Table I indicate that the average set of fruit in 1930 was higher on the irrigated than on the dry plots. In 1931, on the other hand, the trees on the dry plots produced a higher percentage of blossoms than did those on the irrigated plots. Consequently, it is impossible to conclude definitely from these data whether or not there was a direct influence of the moisture supply on fruit bud formation.

In order to determine to what extent the moisture supply of the soil was responsible for differences in fruit bud formation, correlation charts for the two varieties were prepared and are shown in Figs. 1 and 2. These charts show a high degree of correlation between the crop produced in 1930 and the percentage of flowering points the following spring. On the Oldenburg variety this correlation is almost entirely independent of the soil moisture conditions during the previous growing season. In other words, in this variety there apparently was no correlation between moisture supply and fruit bud formation.

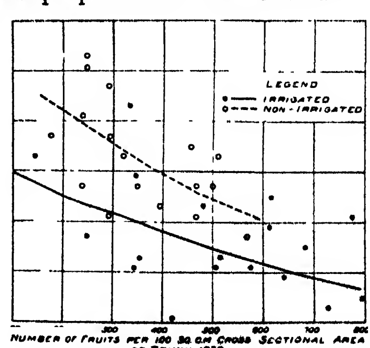

FIG. 2. Correlation curves showing relation of percentage bloom in 1931, to number of fruits produced in 1930, per 100 sq. cm. cross sectional area of trunk, on irrigated and non-irrigated Rome Beauty apple trees.

With the Rome Bauty, on the other hand, there was a rather pronounced tendency for the non-irrigated trees to form more fruit

buds than were formed on irrigated trees bearing a comparable crop the previous year. In this variety the greatest amount of fruit bud formation occurred under conditions of moisture shortage.

Other data collected at Hancock indicate that the Rome Beauty can be caused to form fruit buds considerably later in the season than can the Oldenburg variety. It is possible that the Oldenburg variety may have passed beyond the point where fruit buds could be initiated before the drouth conditions had become so acute as to influence fruit bud formation. The Rome Beauty variety, on the other hand, was in all probability in a condition permitting fruit bud formation at this time. This would account for the difference in results obtained with these two varieties.

During the same season irrigation tests were conducted in a block of York Imperial and Wealthy trees located on very shallow shale soil. These trees were extremely devitalized. They had set a heavy crop in 1929 which did not reach marketable size. In 1930 there was practically no bloom on the trees of either variety. One plot of these trees was irrigated throughout the season of 1930, while the other plot remained dry.

Both varieties showed a higher percentage of fruit buds in the spring of 1931 on the trees irrigated during the previous season than on the non-irrigated trees. This would indicate that on trees not bearing a crop, and which were in an extremely devitalized condition, the addition of moisture tended to increase fruit bud formation for the following season.

The data presented here indicate that during a dry season irrigation does not directly increase fruit bud formation on trees bearing a heavy crop of fruit. In the Oldenburg there was no correlation between moisture supply and fruit bud formation, while in the Rome Beauty the trees that became dry formed a greater number of fruit buds. In seriously devitalized trees which had suffered severely from drouth previously, and which did not carry any crop, irrigation tended to increase the fruit bud formation.

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Some Effects of Different Cultural Methods Upon Root Distribution of Apple Trees

By JOSEPH BECKENBACH and J. H. GOURLEY, *Ohio State University, Columbus, O.*

EXPERIMENTAL work has been carried on for several years in an effort to evaluate such yield differences as arise from the practice of different methods of orchard culture. The purpose of this investigation has been to study the differences in root distribution which might be attributed to these various cultural methods. It is generally admitted that moisture content of the soil, soil aeration, nutrient availability, soil temperature, and soil acidity may be modified by different cultural practices. Soil texture can be altered slightly in the top few inches by the addition of organic materials, or to a greater depth by tile drainage and root decomposition.

The present work was done in four of the orchards at the Ohio Agricultural Experiment Station at Wooster. The soil throughout this part of the farm is quite uniform, being for the most part of Wooster silt loam, which is a rather deep, open soil, without the impervious subsoil strata often encountered in poor orchard soils. There are a few places where the subsoil is heavier, and has resulted in a high water table at some time, due to poor drainage. There was found in some places a Canfield, and in others a Trumbull soil.

Two of the four orchards studied were in sod, one had 10-year-old Stayman Winesap trees which had been seeded down for the past 5 years, and the other 32-year-old Grimes Golden trees which had been in sod from the beginning. One orchard has been cultivated with a rye cover crop since it was planted and contained 10-year-old McIntosh and Grimes Golden. The fourth orchard was composed of 40-year-old trees and is divided into two sections. Beginning at the age of 5 years the whole orchard was heavily mulched. After 29 years of this treatment part of it was plowed up and for the past 6 years it has been tilled. The remainder of the orchard has been continued under the mulching system. A tree from each of these sections was included in this study.

In the investigations of root distribution a trench was dug from the base of the trunk at an angle of 90 degrees with the tree row. The excavation was made as deep as roots were found, and was continued as far out as roots occurred, except where those from the opposite row were encountered, which made definite observations impossible. In practically every case, the distance was at least 20 feet, which was just half the distance between the rows in the younger orchards, and more than half the distance in the oldest one where the tree rows are 33 feet apart.

One side of the trench was measured off into square feet, and string run from nails located in the wall of the trench at intersection points. The trench when ready for the actual root count pre-

sented a checkerboard appearance. The count was recorded directly on graph paper, to a scale of 1 inch to 1 foot.

The outline of the trench was first charted on the paper. With the aid of Dr. G. W. Conrey, the different soil horizons, A, B, and C, with their subdivisions, were drawn on the charts. Care was taken to keep the roots graphed in the proper horizon, as well as in the proper square foot of wall. Before each square was charted the exposed surface of the trench wall was picked over with a screw driver, so that all roots would be visible.

In taking the count, the following root diameters were kept separate by the use of different colored pencils: Up to 1 mm, 1–3 mm, 3–5 mm, 5–10 mm, 10–20 mm, 20–30 mm, 30–40 mm, and 40–50 mm, a plan reported by workers in New York State. As the charting continued, peculiarities in the soil horizons, the location of tile drain, etc., were noted on the record.

Probably most interesting of all the results were those which had to do with the mulched trees. Where the mulch had been accumulating for 35 consecutive years, a solid mat of mulching material varying from 3 to 6 inches covered the soil. Throughout this mat were thousands of fibrous roots, which were so thick that a regular count could not be taken from the side of the trench. However, at a point 8 feet from the trunk a square foot of mulch was lifted and the roots carefully separated from the decomposing mulch and weighed. The depth of the mat at this point was very little over 3 inches, and the roots therein weighed 59 grams. With very few exceptions, these roots were all less than 1 mm in diameter. None was greater than 3 mm.

Beneath this mat of mulching material and roots, a network of larger roots, with diameters up to 40 mm, was found on the top of the soil. Furthermore, as many or more roots were found in the soil horizons under the mulch as in the unmulched ones. This condition probably explains the fact that the yields were not reduced in that part of the orchard which was changed over from mulch to tillage, despite the fact that great numbers of the surface roots were cut off when it was plowed in the spring, 6 years ago. With the loss of such an extensive part of the root system, one might expect a lowering of vigor and yield; none occurred, however, and so the remaining root system must have been adequate for the demands of the trees. If the orchard had been first plowed under conditions of extreme drought the results might have been quite different.

Little difference was noted in the root distribution of the trees grown under sod and under the cultivation and cover crop methods.

In the course of these studies, information of a more general nature was obtained which suggests the desirability of a change in the distribution of fertilizer applications, particularly in tilled orchards. In every trench excavated, two trends of root concentration were observed, a general decline in number from the surface down into the C horizon, and a general decline from the base of the

tree outward. Both of these trends were constant in every trench dug, regardless of soil horizons included. Likewise, they held true for roots of all sizes.

The following figures are based on foot distances, rather than by horizon layers, because it is assumed that due to fluctuations in the thickness of the horizon layers, a definitely measured distance would give a more complete picture of distribution. A count by horizons proved very similar to one by foot layers.

The greatest number of roots recorded was that of the fibrous ones 1 mm or less in diameter, as might have been expected. In an average computed from all trees investigated, there were 411 fibrous roots in the surface foot of soil, 225 in the second, 98 in the third, 61 in the fourth, 44 in the fifth, and 6 in the sixth foot. A study of the distribution of the larger roots results in a similar curve.

Actual count in vertical sections of soil, including all roots less than 1 mm in diameter, showed a decreasing gradient from the very base of the trunk out to the end of the trench, an approximate 20-foot distance. Inasmuch as most fertilizer recommendations have been made on a basis of application in a ring near the drip of the branches, attention is here directed to the much wider distribution of roots in the soils studied. This would suggest the application of fertilizer not only beneath the branches but more nearly over the entire land area of an orchard 12 or more years old, and recommendations to this effect will be made for many Ohio orchards. Such "all over" applications would need to be applied quite early to avoid absorption of the nitrogen by the grass roots.

The Effect of Submerging the Roots of Apple Trees at Different Seasons of the Year

By A. J. Heinicke, *Cornell University, Ithaca, N. Y.*

ORCHARD soil studies in western New York and elsewhere have clearly shown that the lack of good internal drainage is responsible for relatively poor performance in many orchards (1). Unfavorable soils are not necessarily wet throughout the growing season, but the water table tends to come close to the surface in early spring and after prolonged and excessive rainfall. The following study was designed to demonstrate the effect of submerging the roots of apple trees for varying lengths of time and at different seasons of the year.

Materials and Methods

In the spring of 1930, approximately 100 1-year McIntosh trees were planted in 3-gallon galvanized buckets which were provided with holes in the bottom. The trees made good growth and in the fall of that year they were divided into 10 uniform lots of 7 trees each. Some lots remained without further treatment; others were placed in larger pails and covered with water to a depth of 3 inches above the surface. The earth was heaped around the sides of all pails and of the containers with water. They remained outdoors until about the middle of March when they were brought to the greenhouse. The experiment was repeated 2 years in succession with approximately the same treatment.

Results

Table I gives the periods during which the trees were submerged while in a dormant or nearly dormant condition, and the results in general terms for each treatment.

TABLE I—Effect of Submerging Apple Roots During the Dormant Season and Late Spring

Lot	Period Submerged	Result
Check	None	Normal growth
1	Oct. 20–Nov. 4	Same as normal
2	Oct. 20–Dec. 5	Same as normal
3	Oct. 20–Mar. 17	Same as normal
4	Dec. 5–Mar. 17	Same as normal
5	Mar. 17–Apr. 1	Slight bronzing low leaves
6	Mar. 17–Apr. 15	Slight bronzing low leaves
7	Mar. 17–June 10	Leaves small, light green; growth stunted

It is evident from this study that the roots could be submerged from late fall before the ground is frozen, to the late spring after the ground is thawed out, without causing any noticeable injury.

If the water is drained from the trees before there is any appreciable growth, there seems to be no ill effects from the treatments. On the other hand, if there is any leaf surface present while the roots are still submerged in water, there is likely to be severe damage, provided the trees remain in water for more than 2 weeks, and also provided they are exposed to high temperature or other conditions which cause excessive transpiration.

TABLE II—EFFECT OF SUBMERGING ROOTS AFTER FOLIAGE IS FORMED

Year	Period Submerged	Result
1931	1. June 10–June 18 2. June 10–June 26	All normal until June 17 Injury to ¼ of trees June 18; temperature 101 degrees F. Injury more severe with longer treatment
1932	3. June 1–July 1 4. June 1–Aug. 1 5. June 1–Nov. 1	Same as normal Leaf injury first appeared on hot days. Normal green color regained after Aug. 1 in (4). Early defoliation in (5). None dead.

Table II gives the results obtained with trees that have been flooded after the leaves are fully open. Here again, the foliage may remain normal for more than a month, but if there is a single day of high temperature, the leaves show very serious injury within a few hours time.

The primary cause of injury due to submerging is undoubtedly a lack of oxygen which is responsible for the black color of the roots and the general lack of vigor. The nature of the injury may be noted briefly as follows:

(1) Root growth restricted. Few rootlets. Some dying back of extremities. Color black (normally brown). New roots tend to push from trunk at surface of water.

(2) Small leaves, light green. Margins of leaves yellow-bronzed. Twigs spindly.

(3) Severe injury on hot days. Toasting, stippling, or burning of leaves. (Trees in dry soil may show "crisp green" leaves). Injury may occur on leaves on one side of tree, or adjacent parts of leaves.

It should be noted especially that if trees on well drained soils are allowed to suffer for water on hot days, a quick drying out of the leaf occurs which brings about a "crisp green" appearance rather than the bronzed or toasted condition referred to above.

Discussion

Paradoxically, the high water table causes injury to the tree because it interferes with the water supply to the leaves. The rootlets are injured, which in turn makes it more difficult for the water to be taken into the larger roots. Where transpiration is not excessive, the leaves may carry on for some time under this handicap, but they are constantly endangered at high temperatures.

Under orchard conditions, high water table is often associated with a poor set of fruit and with weak growth (2). High water

tables are most likely to occur on poorly drained soils in the late spring. When the flowers are opened there is considerable leaf surface developed which may require more water than the submerged and restricted root system can supply. The first organs to suffer are the flowers whose abscission layer soon forms. Sooner or later the leaf and shoot growth also begin to show injurious effects. Attention should be called to the fact that orchards subjected to periodic flooding sometimes come through without any apparent injury. In all likelihood this is because excessively high temperatures have not prevailed during the time the trees have been submerged.

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Response of Fruit Tree Growth to the Soil Complex Reached by the Roots

By J. O. Veatch and N. L. Partridge, *Michigan State College, East Lansing, Mich.*

NEW concepts of soil, or modifications of old concepts, have attained wide acceptance among soil scientists during the past few years. The development of the subject of morphology in soils has a direct bearing on horticultural science. This branch of pedology embraces the study of the soil profile, the subdivision of a soil into its natural layers or separate parts, termed *horizons* in a mature soil, and the study of the chemical and physical nature of the anatomical parts in relation to the genesis of the soil and in relation to the growth of plants. As a result of such studies, it becomes evident that the old, and still common, subdivision into *soil* and *subsoil* is no longer adequate for the proper understanding of the phenomena of plant growth in relation to the soil.

The major parts, or master horizons, of the mature soil profile are commonly designated by the letters A, B and C, which represent respectively: (A) the surface horizons in which there has been maximum removal of components; (B) the horizons in which there has been maximum concentration or deposition of colloids, iron, alumina, and lime; (C) the parent material or geological substratum. Diagrams representing such soil structure are reproduced in Figs. 1 and 2. Each of the major horizons may be subdivided so that a complete profile may contain six or more layers differing from each other chemically and physically, and which may offer more or less distinct environments for root development. It is understood that in any region of diversified geology and topography there will be considerable land on which the soil profile may be incomplete, due to youthfulness of the surface or to modification caused by erosion.

The concept of the soil profile and the recognition of the soil type, we believe to be fundamental in orchard soil studies. The first work in such studies is the acquisition of facts regarding the distribution of tree roots in relation to the soil horizons in conjunction with studies on moisture, availability of nutrients, penetrability, reaction, and other chemical and physical facts regarding the separate layers which have a bearing on root development and which influence tree growth. This knowledge is basic in studies of orchard soil management regarding the kind of cultivation, use of cover crops, fertilization, and irrigation best adapted to any particular soil. The soil profile provides the criteria for the establishment of the soil type and phase. By observation and measurement a soil type may be evaluated on the basis of tree growth, yield, and quality of fruit. It is essential to recognize the differences in the trees induced by differences in management and to deal with condi-

tions in many orchards before making a final estimate of the relative horticultural value of different soil types. Finally, the geographic distribution of the types may be observed on the soil map and the extent and acreage of different economic classes of orchard land determined for the area.

Both intensive studies of restricted areas and extensive qualitative observations of growth in relation to different profiles and soil types have been initiated in Michigan. Such work is still in a pioneer stage and it is realized that a very large number of field observations and laboratory determinations must be made before dependable correlations can be announced. Present experience has

Fig. 1. Diagram representing the soil horizons and root distribution observed in the lighter soils. Tree I is on Plainfield sand and Tree II on Bellefontaine sandy loam.

shown that the most promising results can be obtained from a coöperative project involving both the horticulturist and the soil scientist, and further that a balance between field, laboratory, and office work must be maintained in order that theories and observations may be checked one against the other.

Since it is inexpedient at this time to present detailed observations and to describe all of the minute differences in profiles of the soils in the areas in which the authors have worked, only illustrative and suggestive relationships will be given. The diagrams reproduced in Figs. 1 and 2 represent the rooting habits of fruit trees on some of the soils used rather extensively for fruit production in Michigan. Variations in the nature of the horizons cause differences in the distribution and extent of the roots in the soil. However, the depth, thickness, and texture of the various horizons are not uniform even within a single soil type. From the point of view of tree growth and production, the distribution of the roots, laterally and in depth, is relatively unimportant provided sufficient permanent supplies of moisture and minerals are reached. If an abundant store is close at hand, the roots need not penetrate so

deeply nor extend so far as in soils lower in fertility and less able to furnish moisture continuously.

In Michigan, the parent material of practically all of the soils consists of unconsolidated deposits of glacial origin. There exists a wide textural range in materials from pure sand, sand and gravel, friable sandy clay, and silt to compact, massive, nearly pure clay. There is also a range in lithologic composition with corresponding differences in the soil profiles, both under well drained and wet conditions. On the deep, dry, easily penetrable sands in which there is a dry C horizon and only a faint development of a clayey B

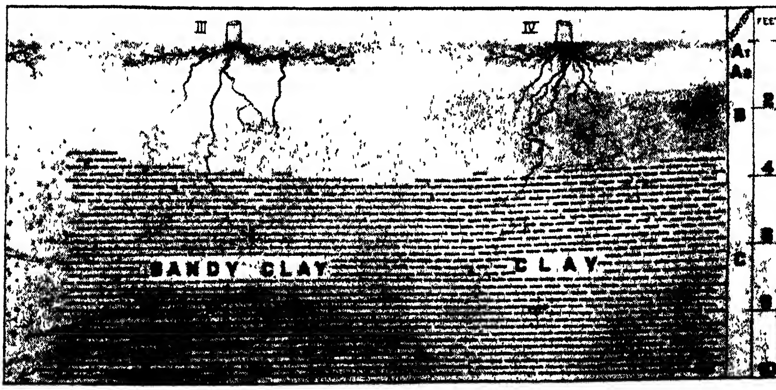

FIG. 2. Diagram representing the soil horizons and root distribution observed in heavier soils. Tree III is on Miami loam and Tree IV on Nappanee silt loam.

horizon, there is a notable development of long lateral roots and a mass of fine roots in the surface (A) horizon but with relatively few in the lower horizon (Tree I in Fig. 1). Owing to the scanty supply of moisture reached by the roots, trees set on soils of this character usually make a slow growth. When old orchards are encountered, a large proportion of the original trees usually have perished and numerous vacancies or resets are observed. The soil is usually acid to a considerable depth.

A second common soil condition comprises (1) sandy loam surface horizons, (2) a clayey and retentive but penetrable subsurface horizon of variable thickness; and (3) a relatively dry limey gravel and sand substratum. Here there is the usual extensive root development near the surface, but proportionately less than in the dry sand; a second horizon showing less extensive development of roots; a third horizon in which there is a more extensive development; and finally a fourth horizon, the substratum, in which there are relatively few roots but occasionally mats of fine roots are found in the silt or clay pockets (Tree II in Fig. 1). It is probable that trees set in this soil are abundantly supplied with lime, at least after a few years of growth, notwithstanding the usually acid reaction of the surface soil since lime is usually present in the B and C

horizons. Given the same spacing, trees will exhibit greater volume of growth other things being the same, than on the first or extremely sandy soil. Many successful peach orchards are found on this kind of soil.

A third soil condition consists in brief of (1) a silty and loamy surface soil of medium, but greater, fertility than the soils previously described; (2) a gray leached acid silty horizon; (3) a compact retentive clay horizon; and (4) a compact, retentive, limey clay, jointed but not easily penetrated. There is the usual strong root development in the surface horizons but a less extensive lateral development than in the first two conditions; fewer roots in the gray and rust-colored acid subsurface horizons, but an increase in the B horizon; and lastly, a few large roots but a number of separate mats of fine roots in the joint planes where apparently lime, moisture, and elements of fertility are available (Tree III in Fig 2). This soil complex produces a vigorous growth of apple trees, many long-lived, profitable orchards being observed on it. There is a sufficient reserve of moisture in the B and C horizons, which the roots can penetrate so that a sod does not draw moisture and nutrients to the serious detriment of the tree.

The fourth condition illustrated (Tree IV in Fig. 2) is the heaviest of our upland soils. The strong root development in the surface horizons is even less extensive laterally than in the third condition. The B horizon is harder and more difficultly penetrable, and the roots, following the joint planes, are tortuous and often distorted. The underlying C horizon is more compact and although it is penetrated by the roots, they grow slowly and do not usually reach any considerable depth. Top growth is apparently restricted by the slow root development and the trees do not attain the size of those on the third soil condition. Unless the topography is such that surface drainage is provided, there are frequent spots where the trees are injured by standing water. Although occasional orchards set on this soil are successful, it is not usually as satisfactory a soil condition as the third.

A soil condition, widespread in Michigan, consists of a variable cover of loose sand over relatively impervious clay. Soil profile conditions obtain according to the thickness of the sand, and other factors, resulting in types ranging from excessively dry, where the clay is very deep, to hardpan and waterlogged soils where the cover is thin. A series of soils may be established, each division having its own peculiar variations and profile with corresponding differences in root development and distribution. Each soil or orchard site type will be found to have practical significance. In this series, the presence of an acid hardpan has an unfavorable influence on root development and hence on the growth of the tree, this varying directly with the depth, thickness, and degree of induration of the pan. Again in this series, the soil profile may exhibit a horizon directly above or at the top of the clay which contains iron oxide, manganese oxide, and possibly soluble aluminum compounds to-

gether with intermittently waterlogged conditions, all of which are decidedly unfavorable for the successful growth of the tree. Individual trees in commercial orchards on soils of this series may show good, poor, or fail in growth, depending on (1) whether the roots have penetrated the dry sand into the underlying clay, (2) whether the roots are concentrated in the surface horizons as in the deepest and driest sands, or (3) whether an acid hardpan or waterlogged horizon are present at shallow depths.

A few intensive studies have been undertaken wherein the peculiarities of each individual tree are correlated with rather minute differences in the profile or with erosion phases of the soil type. Some preliminary conclusions from these studies have been published elsewhere (1).

As a result of our investigations to date, it is proposed in further studies to be guided by the principle: The nature of the growth of the tree, so far as this is a factor of soil, is a function of a complex consisting of all the soil thickness through which the roots penetrate. The appraisal of a soil or the explanation of any particular phenomenon of growth which may be related to the soil cannot be made on the basis of tests or examinations of the plow soil alone, since the subsurface or even the deep substratum may be equally important. In other instances, variations in the lower horizons may be of a sort that are relatively unimportant or masked by differences in the A horizon (2). The importance of this principle is strikingly evident in attempts to correlate the growth of a fruit tree with pH, or degree of active acidity of the soil. In numbers of instances, soils exhibit a range from about 4.5 to about 7.5, depending upon the depth or the separate soil horizon examined. The roots of a single mature apple tree are found in all these horizons with their diverse conditions, thus making a correlation with any single pH of any of these layers of doubtful significance. Analogous ranges in moisture, inorganic colloids, and nutrient elements such as phosphorus and potash may be observed. It follows that correlations with any factor or factors of a single layer are likely to be inconsistent over any considerable area. The soil is a complex. Consequently, a study of a portion of the soil and a part of the root system is not sufficient to determine the soil conditions which influence tree growth and productivity. A type, or minor unit, in a natural classification of soils, is a collective expression of those factors which influence tree growth. Necessarily, the most valuable correlations can be made with soil types rather than with any single physical or chemical condition.

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The Rooting Habit of Deciduous Fruits on Different Soils

By JOSEPH OSKAMP, *Cornell University, Ithaca, N. Y.*

IN a study of soils in relation to fruit growing in New York it has been shown that mature apple trees vary widely in depth of rooting, from 2½ to 8½ feet in one area, depending on the character of the subsoil and substratum, deep rooted orchards being almost invariably productive but the converse not always being true.[1] The present paper deals with other deciduous fruits in a less extensive way, so that the results are suggestive rather than conclusive. Where the fruit is mentioned it will be understood to refer to the following varieties: Baldwin apple, Montmorency cherry, Elberta peach, Bartlett pear, and Italian prune.

Root systems were examined by means of a standardized excavation at right angles to the general spread of the roots, at a distance of 10 feet from the trunk to the inner face of the excavation in the case of mature apple trees and 6 feet from the trunk in the case of young apple trees and other fruits. The excavation in all cases was a rectangular pit bisecting the root system, 10 feet long, 2 feet wide, and to a depth that no more roots were encountered. A map or chart was then made of the exposed root ends as they appeared on the cut surface of the excavation toward the tree. These were drawn to a scale so that the size and position of all roots appearing on the inner face of the cut was shown. From these records of the numbers of roots the percentage of roots at different depths has been calculated for different soils.

CHERRY ROOTING

Uniform brown profile.—The deepest rooted cherry trees were found on soils derived from water-sorted material where the soil profile was of a uniform brown to slightly mottled color and medium to light texture. The trees examined were about 20 years old and show an excellent distribution of roots in the first 4 feet, with 2 per cent of the roots in the sixth foot, (Table I). This rooting of cherry trees is very much the same as that of apple trees of about the same age on a favorable soil type designated as No. 22 in the Hilton area. Considering the relative size of cherry trees

[1]This is a phase of the larger state program of land utilization, the study of which has been entrusted to the New York State College of Agriculture, at Cornell University. The Department of Pomology has contributed the following publications to date to which the reader is referred for a fuller account of apple tree behavior, soil types and profiles:

1. Soils in relation to fruit growing in New York, Part I, A detailed soil survey of the Hilton Area, Monroe County, by A. T. Sweet and Joseph Oskamp, Cornell Univ. Agr. Exp. Sta. Bul. 541, 1932.

2. Soils in relation to fruit growing in New York, Part II, The size, production, and rooting habit of apple trees on different soil types in the Hilton and Morton Areas, Monroe County, by Joseph Oskamp and L. P. Batjer, Cornell Univ. Agr. Exp. Sta. Bul. 550, 1932.

this certainly compares favorably with the depth of rooting of old apple trees on a somewhat similar soil designated as No. 3 in the Hilton area. Studies made on mature apple trees in the same soil areas as the cherries here reported on, indicate a depth of rooting slightly deeper than the cherries.

In Wayne County where the cherry studies were made the deepest rooting occurred on soils that were laid down in rapid moving

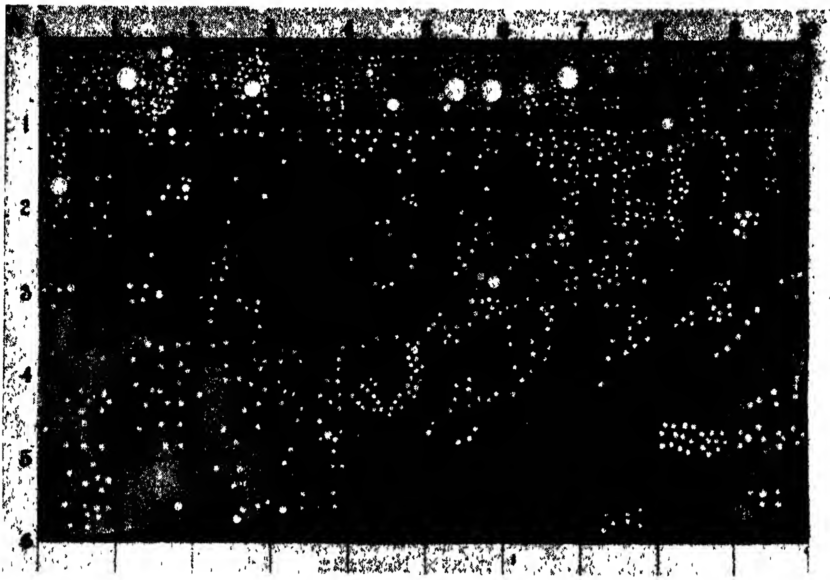

FIG. 1. Typical Rooting of Cherry Tree in a Uniform-Brown Soil Profile of Water-Sorted Material (Wayne 45-21-4-2).

The face of a deep excavation drawn to scale showing the location of roots penetrating five zones of the profile. The natural soil colors are comparatively uniform shades of brown, indicating moderate to rapid drainage. The white dots represent roots exposed on the face of the pit; the root sizes represented from small to large dots, are 0-2 mm, 2-5 mm, 5-10 mm, 10-20 mm, and 20-30 mm.

water and consist of alternating layers of sand and gravel of varying degrees of fineness, with occasional aggregates of silt and clay. A typical soil of this kind formed by outwash from glacial till has been mapped in the Wayne County Soil Survey as the Palmyra gravelly loam; another originating from old beach lines is the Alton. A typical profile of this kind is shown in Fig. 1. Where the water movement has been less rapid and the soil particles grade to the finer sands they have been designated as the Dunkirk series. Where the finer soil particles of silt and clay are encountered in the subsoil and substratum the rooting is nearly as deep as where the more sandy profiles are found, provided the profile retains a brown or only slightly mottled color. Such soils occur in the Dunkirk

and Lucas series in Wayne County and resemble types Nos. 21 and 22 of the Hilton Survey.[3]

TABLE I—ROOT DISTRIBUTION OF CHERRY TREES ON DIFFERENT SOILS

Profile	Type or Type No.*	Depth (Feet)	Per cent of Roots of Various Sizes†				
			0–2 mm Fibrous	2–10 mm Small	10–20 mm Medium	20–40 mm Large	Total
Uniform brown color; light texture; water sorted material	Palmyra gravelly loam, Alton gravelly loam. Resembles Soil No. 3	1	34.9	2.4	0.2	0.3	37.8
		2	18.5	1.5	0.1	0	20.1
		3	13.0	1.1	0.1	0	14.2
		4	15.6	1.1	0.2	0	16.9
		5	8.5	0.4	0.1	0	9.0
		6	1.8	0.2	0	0	2.0
		7	0	0	0	0	0
		Total	92.3	6.7	0.7	0.3	100.0
Gray layer, mottled color; light to heavy texture; water-sorted material	Tyler fine sandy loam and Dunkirk fine sandy loam. Similar to Soils Nos. 16–17	1	44.1	15.7	1.7	0.4	61.9
		2	26.2	4.2	0.2	0	30.6
		3	6.9	0.6	0	0	7.5
		4	0	0	0	0	0
		Total	77.2	20.5	1.9	0.4	100.0
Uniform brown color; light texture; weathered from glacial till	Light textured deep Ontario and Worth. Similar to Soils Nos. 42–52	1	33.8	4.0	0.4	0.2	38.4
		2	32.4	2.0	0.5	0.2	35.1
		3	16.9	0.9	0	0	17.8
		4	8.2	0.3	0	0	8.5
		5	0.2	0	0	0	0.2
		6	0	0	0	0	0
		Total	91.5	7.2	0.9	0.4	100.0
Gray layer, mottled color, medium texture; weathered from glacial till	Medium textured, compact Ontario and Worth. Similar to Soils Nos. 12–14	1	63.4	8.6	1.4	0.4	73.8
		2	19.1	2.3	0.8	0.1	22.3
		3	2.2	0.6	0	0	2.8
		4	0.8	0.3	0	0	1.1
		5	0	0	0	0	0
		Total	85.5	11.8	2.2	0.5	100.0

*The soil type refers to the Wayne County Soil Survey and the numbers refer to the detailed Soil Survey of the Hilton Area (see footnote 1).

†An average of three excavations on each profile; percentage based on numbers of roots appearing on cut face of similar sized excavations.

Soils with practically this same uniform brown profile, but weathered from unsorted glacial deposit and mapped as Ontario loam and Worth loam in the Wayne County Soil Survey, are similar to types designated as Nos. 42 and 52 in the Hilton area. They show a moderately deep rooting of cherry trees. The roots are well distributed through the surface 3 feet. About 8 per cent of the roots are in the fourth foot and only a fraction of a per cent in the fifth foot. The depth of rooting is here limited by the compact gravelly formation of the unweathered glacial till. Similar results were found with apple trees in the Hilton area and with hundreds of other fruit trees the data for which have not yet been compiled.

[3]It should be noted that in all cases where the resemblance between soil types is suggested it refers only to the factors of profile colors and textures as here discussed and does not include acidity and other factors.

The Ontario and Worth loams vary considerably in profile and these cherry orchards only include those on soils having a uniform brown profile, where the subsoil seems to be less compact and trees somewhat deeper rooted than on soils with a less uniform profile.

Gray layer profile.—This profile shows comparatively large variations between horizons. A highly mottled subsoil, a well developed ash colored gray layer or both are characteristic.[3] A profile of this kind is shown in Fig. 2. A soil derived from water-sorted material with a considerably mottled gray layer profile is associated with shallow rooted cherry trees, the roots practically stopping at 3 feet,

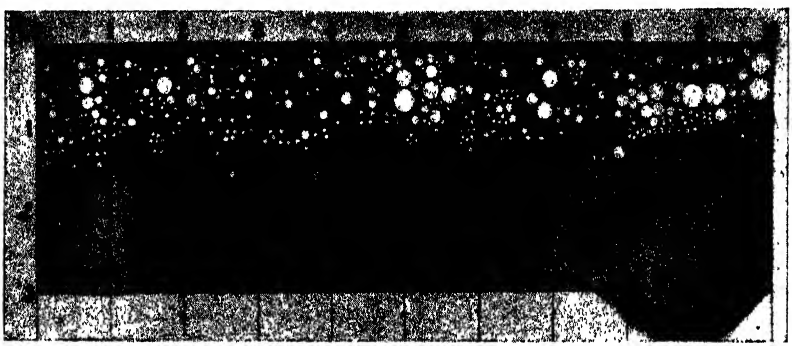

FIG. 2. Typical Rooting of Cherry Tree in a Mottled, Gray Layer, Soil Profile (Wayne 136-3-11-2).

The face of a deep excavation drawn to scale showing the location of roots penetrating four zones of the profile. The third zone from the surface is a definite gray layer, and several iron and manganese concretions appear as black spots in the third and fourth zones, indicating slow drainage and ground water level near the surface. The white dots represent roots exposed on the face of the pit; the root sizes represented from small to large dots are 0-2 mm, 2-5 mm, 5-10 mm, 10-20 mm, and 20-30 mm.

only 1 per cent extending into the fourth foot. This depth of rooting is not unlike that found in apple trees of about the same age on a somewhat similar, although heavier soil designated as No. 18 in the Hilton area.

The soil with the gray layer, water laid profile occupied by the cherry trees reported on in Table I, varies from light to medium in texture and has been designated in the Wayne County soil survey mostly as Tyler fine sandy loam and Dunkirk fine sandy loam and is similar to Soils Nos. 16 and 17 in the Hilton area. The latter soils drain slowly and ground water occurred within 2 feet of the surface in the spring.[4]

Some soils with a similar profile where the rooting of cherries was studied have been mapped as Livingston silty clay loam in

[3]The gray layers and mottlings referred to in this paper are mostly the result of slow drainage or high ground water level.

[4]See footnote 1.

Wayne County. This soil corresponds somewhat to No. 18 of the Hilton survey. The rooting was shallow.

Turning now to soils with a similar profile, but derived from unsorted glacial material, it is seen in Table I that rooting of cherry trees is shallow, there being no roots below the third foot. This is about the same as the rooting of apple trees on a similar soil in the Hilton area, designated as No. 12. In the Wayne County survey some of these soils are mapped as Ontario loam and Worth loam, but are more mottled and slightly heavier and more compact in the subsoil than other soils of these types. Some are mapped as Lockport loam which would more nearly resemble Soil No. 14 of the Hilton area than other soils of that area. Trees are shallow rooted on all of these soils, the particular depth depending on the depth to the compact glacial till.

Peach Rooting

Uniform brown profile.—The depth of rooting of mature peaches on water-laid soils of light texture and uniform brown profile varied from 4½ to 7 feet with 5 feet about the most frequent depth, or not essentially different from apple or cherry trees on similar soil. Most of these soils in the Niagara County Soil Survey were mapped as Dunkirk gravelly sandy loam and Dunkirk fine sandy loam and are similar in several profile characteristics to Soils Nos. 3 and 21 in the Hilton area.

One orchard was examined on a soil of unsorted glacial deposit similar to Soil No. 52 of the Hilton area and the roots stopped at a depth of 3 feet, where the compact glacial gravel was encountered. It is the same type of root behavior that has been experienced with cherries and apples on this soil.

Three of the five peach root systems examined had an appreciable number of dead roots. This was not due to abnormal trees as the orchards were in a thrifty condition and the trees were typical.

Gray layer profile.—These soils varied from light to heavy in texture with distinct mottling and correspond to the Clyde fine sandy loam, Dunkirk clay, and less well drained areas of Dunkirk loam of the Niagara County Soil Survey. They are similar in some respects to the imperfectly drained lacustrine soils of the Hilton area.

The depth of rooting of peach trees is less on soils with a gray layer profile. It varies from 3 to 4½ feet, 3½ feet being the most frequent depth. Six out of the nine root systems examined had a considerable number of dead roots. Thus more or less dead roots seem to be a characteristic of peaches under a variety of soil conditions. With the other fruits examined only occasional dead roots were found except in very unfavorable soil where a high ground water level was indicated. It seems reasonable to suppose that the considerable mortality of peach roots may be related among other things to the consistently heavy pruning that this fruit receives.

If left unpruned, however, it will accomplish natural thinning by the death of many branches, so that the mortality of parts may be an inherent characteristic.

Pear Rooting

Indications are that pears will root fully as deep or deeper than apples on a heavy soil type. Fire blight, and pear psylla, have been so difficult to control in pear growing as to make orchards exceedingly uneven. The difficulty in obtaining comparable orchards for purposes of comparison is therefore very great and sufficient records are not available to indicate behavior on different soils.

Prune Rooting

The prune was an exception to the other fruits, rooting as deeply on heavy soils with a well developed gray layer, as on lighter soils with little gray layer development. The rooting was deep, namely, 6 to 7 feet on water-laid soils. On some of these same soils with a gray layer, peaches did not root over 3 feet deep.

It is interesting to note, however, that prune trees on soils of unworked glacial material are definitely limited in depth of rooting by the depth to the compact, slightly weathered glacial till, in common with the other fruits studied.

Yield and Stand of Trees

The data in Table II at least suggests that there is a relationship

TABLE II—Yield and Stand of Fruit Trees on Soils with Different Profile Characteristics

Area	Fruit	Profile*	Age Group	Numbers involved in Yield Record		Average Yield per Tree, 3 Year Period	Per cent of Full Stand	Average Depth of rooting (Inches)†
				Orchards	Trees			
Williamson	Cherry	Uniform brown	12–25	14	2,586	108 lbs.	90	55 (6)
		Gray layer	12–25	24	6,215	63 lbs.	82	27 (9)
Olcott Youngstown	Peach	Uniform brown	10–20	11	6,318	2.9 bus.	81	61 (5)
		Gray layer	10–20	16	9,553	1.7 bus.	65	40 (9)
Youngstown	Prune	Uniform brown	15–25	5	1,142	2.2 bus.	90	73 (2)
		Gray layer	15–25	9	4,258	1.0 bus.	83	74 (4)
Hilton Morton‡	Apples	Uniform brown	45–65	25	3,466	7.4 bus.	85	71 (11
		Gray layer	45–65	12	1,445	2.6 bus.	77	43 (8)
Hilton, Morton‡	Apples	Uniform brown	15–25	15	1,858	3.2 bus.	94	47 (4)
		Gray layer	15–25	16	1,914	1.5 bus.	87	38 (4)

*Uniform brown profile includes slight mottling; gray layer profile includes pronounced mottling.

†Figures in parenthesis indicate the number of root excavations included in the averages.

‡Yield records for these areas supplied by T. E. LaMont, Department of Agricultural Economics and Farm Management of the New York State College of Agriculture; culls and drops not included.

between certain soil profile characteristics, the yield, and the stand of different kinds of fruit trees. A uniform brown profile with little mottling is usually associated with deeper rooting, a better stand of trees, and higher production than is a strongly mottled, gray layer profile. The depth of rooting and stand of trees seems to be correlated with the soil profile except in the case of the prune. The prunes as a whole were on a much heavier and more slowly drained soil than the cherries and a slightly heavier soil than the peaches, yet the stand of trees is good even where a gray layer exists. The yield of prunes, however, appears to be reduced under the latter condition.

There are, of course, other factors aside from soil that have an influence on distribution and depth of rooting. One of these is the root stock. Rogers has shown that even dwarf stocks may root deeply on some soils (1). Observations in New York indicate that there is probably as great or greater difference in depth of rooting between the same fruit on different soils, than there is between different fruits on the same soil.

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A Preliminary Report on Root Growth Studies With Some Orchard Trees

By C. F. Kinman, *U. S. Department of Agriculture, Washington, D. C.*

On November 25, 1930, experiments were begun for the purpose of observing root extension and behavior. For this purpose panes of glass were placed upright in the soil near the roots of some bearing orchard trees in the United States Plant Introduction Gardens at Chico, California. Double strength window glasses 2 x 3 feet in size, incased in commercial window frames, were placed near the trees with the upper edge of the glass at the surface of the ground. The glass was placed about 2½ to three feet from the trunk of the trees, the distance being determined by the root population in the soil, as it was desired to have one or more roots of ¼ to ¾ inch in diameter and several smaller ones in the 2 x 3 foot area.

To install the glass and provide room for observations it was necessary to dig pits a few feet in length which could be readily opened when visits were made. To prevent changes in temperature in the pits and to exclude light a board covering was fitted against the window sash and the pits were then filled and heaped with straw.

On December 5, 1931, additional glass was installed and this time board coverings that were lined with celotex were used, one to fit against the glass and another to cover the pit. This last method has been reasonably satisfactory and is a decided improvement over the straw-filled pits.

When installing the glass an attempt was made to fit it tightly to the earth bank, but this was abandoned on account of the difficulty of its accomplishment. It was found that any thin spaces left between the glass and soil could be filled easily by pouring in dry sifted sand after the glass had been secured in place. The glass is held in position by pegs, several inches in length, driven into the side walls and bottom of the pit. These pegs hold the sash firmly and still give enough when crowded by the pressure of growing roots to protect the glass from being broken.

The Myrobalan, peach, and apricot trees in the test, are all in full bearing and are growing in a deep, fertile, friable, dark loam. All trees used in the experiment had shed their leaves before the glass was installed as a number of sharp frosts had occurred previous to that time. The peach and apricot trees are of the same age and are growing in adjoining spaces in an orchard row, and the bearing Myrobalan is separated from them by only a few tree spaces.

Trees were irrigated on June 29, September 1, and October 10; but insufficient soil moisture at times may have been responsible for the lapse of root activity during the summer of intense heat and uninterrupted drought. The summers at Chico are very hot,

the humidity very low, and almost the entire rainfall occurs between October and the following May. The mean temperatures at this place during the winter months are: November 53.8, December 47.5, January 46.9, and February 50.3.

The progress of the roots is recorded by marking on the glass with colored wax pencils. By employing different colors on succeeding visits the record of a number of observations is left on the glass.

Since the installation of the glass on November 25, 1930, observations have been made at intervals of about 2 weeks. The first date at which new roots were seen back of the glass was on February 3, or 70 days later. A small number of roots of the Myrobalan and the peach were then a few days old. Apricot roots showed their first new growth 2 weeks later. For several weeks after the new roots appeared there was a rapid increase in their number and length in the case of all three trees. A summary of the root growth observations is presented in Table I.

The average maximum extension of all roots in sight for the Myrobalan for any 2-week period was made during the period ending April 13, when it reached 3 2 inches. The maximum average extension for the peach was made during the period ending May 4, when it reached 3.4 inches, and the maximum for the apricot, 4.5, was recorded on July 4. On May 4 and May 21 an average extension of 3.7 inches was recorded. During early spring the Myrobalan roots made more growth than did the peach, which in turn did better than the apricot. The seasonal periods of maximum activity also occurred in the same order. The Myrobalan and peach trees blossomed 3 to 4 weeks after the first new roots appeared. This intervening time for the apricot was somewhat shorter. After the date of maximum root growth there was an abrupt decrease in activity of roots of all trees until on June 1 no extensions were recorded for the Myrobalan and peach, and no further extensions by the Myrobalan were recorded until September 11, when a second period of activity started and continued until into November. With the exception of one examination, no extensions were recorded for the peach from June 1 until October 21. Only a few apricot roots increased in length from June 1 to October 21, although at least a few extensions were recorded at all visits from early spring throughout the remainder of the year and until January 6, the last date of the season that growth was recorded.

On December 5, 1931, or about a year after the first glass was installed, additional installations were made beside apricot and peach tree roots. Olive trees were added to the experiment at this time. At this installation redwood sash instead of those made of pine were used and they have proved preferable to the pine. For the 1932 season no root extensions were seen back of the glass installed either in November 1930 or December 1931 until February 23, when the first peach roots appeared. The first apricot root growth was recorded on March 7. It is notable that the new roots of olive trees

were first observed during the visit of March 28. The olive is normally much later in blooming than are the deciduous trees discussed

TABLE I—Number and Average Extension of Growing Roots Against Glass Surface as Recorded at Successive Visits to Orchard Trees, Chico, Calif. One 2 x 3 Foot Glass was Installed for Each Tree

Date of Visit	Myrobalan		Peach		Apricot	
	Number of Growing Roots*	Average Extension (Inches)	Number of Growing Roots	Average Extension (Inches)	Number of Growing Roots	Average Extension (Inches)
Glass Installed November 25, 1930						
Jan. 15, 1931	0	0	0	0	0	0
Feb. 3, 1931	42	1.4	7	.5	0	0
Feb. 17, 1931	74	2	13	1.5	1	1
Mar. 5, 1931	79	1.8	17	1.1	3	1
Mar. 21, 1931	66	2.6	21	1.2	14	1.8
Apr. 13, 1931	69	3.2	34	3.1	25	3
May 4, 1931	19	2.5	24	3.4	21	3.7
May 21, 1931	6	1.6	9	2	10	3.7
June 1, 1931	—	—	—	—	1	2
June 15, 1931	—	—	—	—	3	3
July 4, 1931	—	—	3	2.3	4	4.5
July 21, 1931	—	—	—	—	9	2.4
Aug. 3, 1931	—	—	—	—	6	2.1
Aug. 22, 1931	—	—	—	—	7	1.7
Sept. 11, 1931	5	2.1	—	—	4	2
Oct. 1, 1931	3	2	—	—	9	1.6
Oct. 21, 1931	3	2	33	3.8	25	3.2
Nov. 6, 1931	1	2	30	2.2	23	2.5
Nov. 19, 1931	—	—	23	1.1	24	2.4
Dec. 5, 1931	—	—	—	—	2	2
Jan. 6, 1932	—	—	—	—	2	1
Jan. 22, 1932	—	—	—	—	—	—
Feb. 8, 1932	—	—	—	—	—	—
Feb. 23, 1932	—	—	—	—	—	—
Mar. 7, 1932	2	1.2	6	.7	—	—
Mar. 28, 1932	3	1.5	13	1.2	6	1.1
Apr. 18, 1932	4	1.5	11	2	16	1.2
May 5, 1932	7	.4	9	.8	9	.9
May 23, 1932	1	1.5	—	—	3	.8
June 8, 1932	8	1.8	—	—	—	—
Glass Installed December 5, 1931						
Feb. 8, 1932	—	—	0	—	0	—
Feb. 23, 1932	—	—	11	.6	—	—
Mar. 7, 1932	—	—	23	1.1	1	.5
Mar. 28, 1932	—	—	41	1.5	1	1.5
Apr. 18, 1932	—	—	58	2.1	11	.9
May 5, 1932	—	—	59	1.5	16	1.7
May 23, 1932	—	—	50	3.1	17	2.4
June 8, 1932	—	—	23	1.5	5	2.2
June 24, 1932	—	—	8	1.8	—	—

*Number of roots showing growth since last observation.

in this paper. In the new pits a vigorous growth was made by peach and apricot trees after their first growing dates and until well into the summer, numerous leader roots reaching 2 feet or so in length.

As may be seen in the table, this growth was comparable to that made the previous year by the peach and apricot trees. The extension of roots during this same period in pits dug a year earlier, in November 1930, was much less. The activity of the Myrobalan roots, also, both in number of growing points and average extension, was much greater the first year after installing the glass than the second. The difference in root extension for the two seasons may doubtless be accounted for by the difference of time that elapsed following the root pruning for the installation of the glass.

The number of growing roots that will appear back of a glass when installed in the manner described will depend largely on the root population in the particular location that is chosen. The number of growing roots and their average extension will give an indication of the root activity.

In both seasons most of the root growth that was seen extended outward from a few main centers, that is, from the stubs of roots that were pruned off when installing the glass the previous season. A number of new roots would spring from a root stub that was ½ inch or so in diameter and extend outward over the glass, resembling somewhat the spokes in a wheel, although fewer grew upward than downward or laterally. The extension made by the roots the second season after installing the glass was almost entirely from the terminals of the previous season's growth. These extensions were short and slender. Only a small number of them made sufficient extension in a 2 weeks' period to be conveniently recorded on the glass. It was strikingly evident that the vigorous growth both in 1931 and 1932 resulted from the root pruning that was done when the pits were dug.

Along with the few more or less permanent branches that developed on the more vigorous new roots that grew during the spring following the root pruning, a number of very slender laterals growing at right angles to the leaders were produced. These laterals grow rapidly, extending ½ inch to 1 inch or so in a day, and were seen to reach from 4 to 5 inches in length. As many as 20 of these slender gossamer-like rootlets have been counted on a single linear inch of peach root. These delicate rootlets that permeate the soil proceed from the segment of the root that is from 1 to 2½ weeks old and that are still white and growing vigorously. None were seen except on extensions that sprang from roots pruned the previous season. They do not remain active long after the portion of the root on which they are growing turns brown in color, which in our experiments has been when it is from about 2½ to 3½ weeks old, and they disappear almost entirely during early summer. Sometimes their course may be traced for a while after they disappear by a thin strand of mycelium.

An early summer search in places in this orchard and in other orchards where the soil had been stirred deeply the previous fall and winter and only light surface culture given the following

spring, revealed an abundance of vigorously growing roots, while in adjacent soil in the tree row that was not stirred in the fall or winter and also in the strata immediately below the stirred area, the new extensions were few and short.

The greatest seasonal activity of roots preceded the trees' critical period of need during fruit setting and leaf development, and the performance of pruned roots in the subsoil and in plowed or otherwise stirred surface soil as observed in this test indicates that the results of root pruning is an important factor to be considered when adopting an orchard cultivation practice or when planning fertilizer applications. It seems to warn against late spring plowing of orchards and to favor deep stirring of the soil so as to do some root pruning in fall or winter.

The Assimilation of Carbon Dioxide by Apple Leaves as Affected by Ringing the Stem

By A. J. Heinicke, *Cornell University, Ithaca, N. Y.*

CUTTING through the bark tissues at right angles to the stem is known to bring about an accumulation of carbohydrates above the ring. The treatment may also interfere with the movement of nitrogen and other nutrients, and, under certain conditions, may even affect the water supply to the leaves. It is to be expected that these results of ringing likewise influence photosynthetic activity. To determine the extent of this influence was the purpose of the study reported in this paper. Such information is needed to fully evaluate the results of practices or experiments where ringing treatments are involved. Incidentally, these studies have afforded a means of testing the practicability of an apparatus specially devised for determining CO_2 assimilation of apple leaves under natural conditions.

Methods

The photosynthetic activity was measured by determining the difference between the CO_2 in normal air and of that which has passed over attached apple leaves enclosed in special assimilation chambers. The method used is a simplification of the procedure first suggested by Kreusler in 1885, and used by Brown and Escombe, and more recently by Kostytschew and others. (See Gassner and Goeze (1) for recent bibliography).

The important features of the apparatus are, first, an efficient absorption unit which removes practically all of the carbon dioxide in the air while passing through the solution at the rate of from 50 to 100 liters an hour. A fritted glass filter plate, with pores 30–50 micron in diameter which breaks the air stream into minute bubbles, and the use of 200 cc of .2N KOH solution which is required for the longer runs, account for much of the efficiency.

The assimilation chambers consist of special cups attached to the under side of the leaf. These provide normal conditions with respect to light and air supply, and avoid the harmful effects of excessively high temperatures and of dead air space. Cellophane envelopes, which fit the leaf closely, have been used in some of the experiments. Special valves and flow meters, accurately calibrated at frequent intervals, are required to regulate and measure the volume of air which passes through the assimilating chambers and the absorption towers in a given time. The air is pulled through the system by an electric vacuum pump. A general idea of the equipment used is given by the photograph. As many as eight or a dozen units may be operated at the same time with one pump.

The details of the procedure have been outlined recently (3) and need not be repeated here. While the principle of the method is simple, there are many precautions to be observed in the standard-

ization of the solution, in filling the flasks, and in the titrations of the unused portion of the absorbent. In the calculations of the CO_2 equivalent from changes in the strength of the absorbent, due allowances must be made for the adsorption of carbon dioxide during the operations of filling the flasks and of titration, and during the interval of several hours or even a day while the flasks remain tightly stoppered but are not attached to the towers.

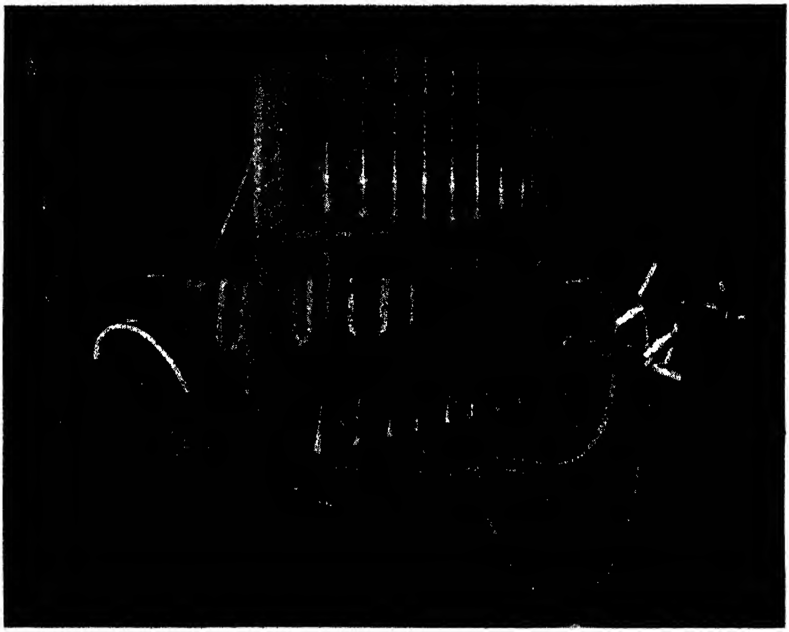

FIG. 1. Apparatus for determining the CO_2 assimilation of apple leaves under natural conditions. Note the special cellophane envelopes and the glass cups used as leaf chambers.

The results are expressed in mgs of CO_2 assimilated by 100 square cm of dorsal leaf surface per hour. The determinations usually last from 4 to 5 hours and the values are, therefore, the average rather than the maximum rates which may be obtained during determinations lasting for briefer periods.

The experiments were all carried out in the greenhouse with 1-year vigorous McIntosh apple trees growing in 10-inch pots, or with 2-year trees cut back and planted in beds. The 1932 shoot growth of these trees at the time of the experiment was from 3 to 4 feet in length and the terminal buds had formed. Ringing was done by removing a strip of bark, 5 mm wide, and protecting the wound by grafting wax. In all of the experiments the leaves which are compared occurred on the same plant and are chosen with reference to similar size and exposure. Preliminary studies on the

apple indicate that two leaves separated by one or two nodes do not necessarily show the same activity even though their exposure to the light is the same. The rate obtained on different days will naturally vary with changes in light, temperature, CO_2 content, water, and other factors, but normally the relationship between different leaves remains fairly constant over a period of several weeks. The activity of these leaves is therefore determined during 2 to 3 days before the stem between the leaves is ringed. If the plant is not moved throughout the experiment, it is assumed that the difference in the relationship between the activity of the leaves before and after the treatment is due to the ringing.

Results

It is clear from the data presented in Tables I and II that ringing of the stem brings about a reduction in the activity of the leaves above the ring. This reduction may show the same day that the

TABLE I—Typical Cases of Co_2 Assimilation of Foliage Above and Below the Ring on the Shoot

Location of Leaves	Days Before or After Ringing		
	1 to 4 Before	6 to 8 After	30 to 35 After
(a) Above ring	16.5*	7.0	3.3
(b) Below ring	13.0	11.9	7.3
Ratio 100 a/b	127	59	45
Reduction	—	47 per cent	60 per cent
(c) Above ring	16.9	8.8	4.4
(d) Below ring	16.0	14.4	10.4
Ratio 100 c/d	106	61	42
Reduction	—	42 per cent	60 per cent

*Expressed in average $Co_2MgHr100Cm^2$.

ringing is done, or it may become manifest after 2 or 3 days. Where the ring heals, recovery of activity is apparent, but if not, the efficiency remains at a low level, until the leaf drops.

In many of our experiments, the leaf below the ring likewise tended to show a reduction in photosynthetic activity after the ringing. This reduction is probably due to the less favorable external conditions that prevailed at the outset, but the possibility remains that the influence of ringing may be responsible in part. This is suggested by the behavior of leaves on an untreated plant (A) in which parallel determinations were made.

While most of the experiments give results similar to those presented above, there is one case out of the plants that have been tried thus far, in which the foliage above the ring seemed to be stimulated in activity by the treatment. This plant happened to be one with very thin light green foliage and may represent a special condition.

TABLE II—INFLUENCE OF RINGING ON CO_2 ASSIMILATION BY McINTOSH APPLE LEAVES

Days	Assimilation in CO_2MgHr100Cm²						
	Plant E			Plant B			Plant A (Control)
	Above (a)	Below (b)	100 a/b	Above (a)	Below (b)	100 a/b	
Before ringing							
4	27.1	22.3	122	14.7	18.7	79	19.0
3	19.3	17.7	109	19.6	20.3	97	17.1
2	29.5	28.2	105	8.5	11.2	76	10.0
1	29.1	31.1	94	16.0	14.8	108	13.5
After ringing							
1	25.9	12.5	207	8.2	10.1	81	8.0
2	11.3	17.0	66	10.0	12.2	82	9.0
3	11.3	16.4	69	11.9	15.1	79	12.5
4	8.2	16.9	49	5.1	9.6	53	6.4
5	7.3	14.7	50	3.7	13.9	27	—
6	4.3	8.6	50	8.3	19.8	42	—
7	18.9	27.8	68	4.9	8.1	60	5.4
8	5.2	9.7	54	9.2	15.6	59	13.2
9	—	—		5.5	11.3	49	9.6
10	9.5	19.4	49	—	—		—
30	—	—		2.7	8.6	31	18.5

In a few cases, the petioles of the leaf were ringed by filing a groove through the phloem tissues on the under side of the petiole, in much the same way that the red humped apple caterpillar does under some conditions. The data indicate that the effects of ringing the individual leaf are in general the same as where the stem is ringed. In one of the experiments a young leaf was ringed before it had attained its full size. In this case the ringing did not seem to interfere with the photosynthetic activity and the ring healed within 10 days.

TABLE III—ASSIMILATION OF CO_2 AS INFLUENCED BY RINGING LEAF PETIOLE

	CO_2MgHr100Cm²					
	(a) Treated	(b) Normal No Ring	100 a/b	(a) Treated	(b) Normal No Ring	100 a/b
Before ringing	10.1	12.3	82	10.2	8.6	119
4 days after ringing	3.1	11.7	26	3.7	7.8	47
6 days after ringing	2.8	11.1	25	6.1	6.8	90

Studies were made also on leaves from which light was excluded to determine the rate of respiration of ringed and normal leaves. While the results are not conclusive, the data tend to indicate that the leaves above the ring give off more CO_2 than those below. There is also an appreciable difference in the temperature of the leaf surface which can be detected by the touch. When the leaf is wrapped about the bulb of a thermometer the foliage above the ring may

register a temperature ½ to 1½ degrees C higher than that immediately below.

A few determinations have been made of the water loss of leaves above and below the ring. The data are not extensive enough to draw any conclusions, but they suggest that the leaves above the ring may experience a water deficit sooner than those below. Where the plants were allowed to suffer for water, the leaves above the ring showed drying before those below the ring.

Discussion

It is evident that ringing under the conditions of these experiments tends to reduce the photosynthetic activity of the leaves above the ring. While the extent of reduction varies, the activity of a leaf on a ringed shoot may be ½ to ⅔ of normal. The low value for apparent assimilation may be associated with an increase in respiration. This may be due to the harmful influence of an accumulation of the products of photosynthesis; possibly also due to the lack of water and nutrients from the soil. If the food material can be removed from the leaf rapidly and utilized by growing tissues, such as new leaf and shoot growth, or for increasing the size of the fruits, the same reduction may not be found.

The data at hand suggest that in interpreting the results of studies on the relationship of leaf area to the development of fruit, (e.g., Haller and Magness) (2) where such studies involve ringing of the branch, it may be necessary to discount the indicated values. It is quite possible that on unringed branches fewer leaves would be required for the work of fully developing fruit than is indicated by the results obtained with ringed branches.

It is obvious from this brief report that studies of the assimilation of CO_2 of the leaves under field conditions provide a useful method of accurately measuring responses of various treatments and conditions long before the results are manifested in other ways. This applies especially to perennial plants, such as fruit trees. The equipment used in the experiments is well adapted for such studies.

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Relation of Leaf Area to Fruit Size and Food Reserves in Apple Seeds and Branches[1]

By A. E. Murneek, *University of Missouri, Columbia, Mo.*

SOME years ago, while investigating the behavior of apple spurs receiving various amounts of defoliation, the writer noted a relationship between the amount of foliage present on the bearing spur and fruit size (1). Thus when only one large leaf (average area 2.49 square inches) was left on a bearing spur of the variety Grimes, the average weight of the fruit was 3.39 ounces. With two leaves per spur (area 5.24 square inches), the fruit weighed 3.74 ounces, and with more foliage (area 11.87 square inches) they averaged 4.49 ounces. It was quite evident, however, from these and other records, that the correlation between leaf number per spur and fruit weight, though obtaining, was not very close, and that practically all the apples were subnormal in size.

Haller and Magness (2) seem to have been the first ones to put this relationship between foliage and fruit size on a more definite numerical basis and to have established the fact that apples are supplied with synthesized food materials at a considerable distance, and, therefore, from other leaves in addition to those of the spur. Further studies by Magness and associates (3, 4) have fully demonstrated that in order to obtain apples of commercially desirable size and quality, 20 to 50 leaves are required per fruit. These and other investigations have put fruit thinning on a more rational basis. More recently Magness and Overley (3) and Aldrich (5) have emphasized also the effects of a comparatively large leaf area per fruit on carbohydrate reserves and increased fruit bud formation and fruit setting in the following year.

The present investigation was undertaken primarily with the object of determining the influence of a relative leaf area per fruit on development and composition of seeds and food reserves in branches, thereby placing emphasis on those phases of the problem which have not been studied or have received only cursory examination. Trees of King David and Ben Davis varieties served as convenient material for this purpose. Selected branches were ringed as soon as the dropping of immature fruit was practically over and it was quite certain that the remaining apples were going to "stick". Most of the rings were on 5-year-old wood. The number of leaves per fruit was adjusted and maintained throughout the season from 10 to 75. Late in the fall, all ringed branches were cut and separated into the requisite parts for all numerical and chemical analyses. The results are presented in Table I and part of the records, for better visualization, in Fig. 1.

It is evident from the data in Table I that with increasing num-

[1]Contribution from the Department of Horticulture, Missouri Agricultural Experiment Station, Journal Series No. 350.

TABLE I—RELATION OF LEAF AREA TO FRUIT SIZE, SEED DEVELOPMENT, AND FOOD RESERVES IN SEEDS AND BRANCHES OF TWO VARIETIES OF APPLES

Number of Leaves per Fruit	Fruit		Seeds				Branches			
							New Growth		Old Growth	
	Av. Diam. (Cm)	Av. Weight (Gms)	Av. Weight per Fruit (Gms)	Dry Matter (Per cent)	Ether Extract (Fat) (Per cent)	Nitrogen (Per cent)	Starch (Per cent)	Nitrogen (Per cent)	Starch (Per cent)	Nitrogen (Per cent)
King David										
10	4.90	48.5	.464	63	26.07	5.08	6.25	1.41	2.85	.43
20	5.41	71.8	.510	62	25.05	5.63	6.94	1.08	4.21	.38
30	6.35	109.1	.556	68	24.11	6.07	9.45	1.05	5.40	.47
50	6.55	128.0	.540	64	24.19	5.71	10.55	.75	6.96	.38
75	7.01	144.4	.562	64	23.05	5.59	11.85	.70	7.30	.41
Normal (not ringed)	5.51	83.1	.531	62	24.13	5.80	7.94	1.21	3.56	.44
Ben Davis										
10	5.87	83.9	.492	59	21.90	5.09	5.11	1.31	1.75	.30
20	6.55	110.1	.538	58	21.35	5.36	6.02	1.31	2.24	.35
30	6.71	124.7	.522	57	20.59	5.50	7.51	1.13	4.34	.38
50	7.16	154.5	.528	58	20.32	5.29	8.46	.85	6.60	.35
75	7.82	178.3	.490	58	20.01	5.24	—	.81	7.30	.45
Normal (not ringed)	6.35	110.7	.537	56	22.67	5.12	6.06	1.25	3.83	.33

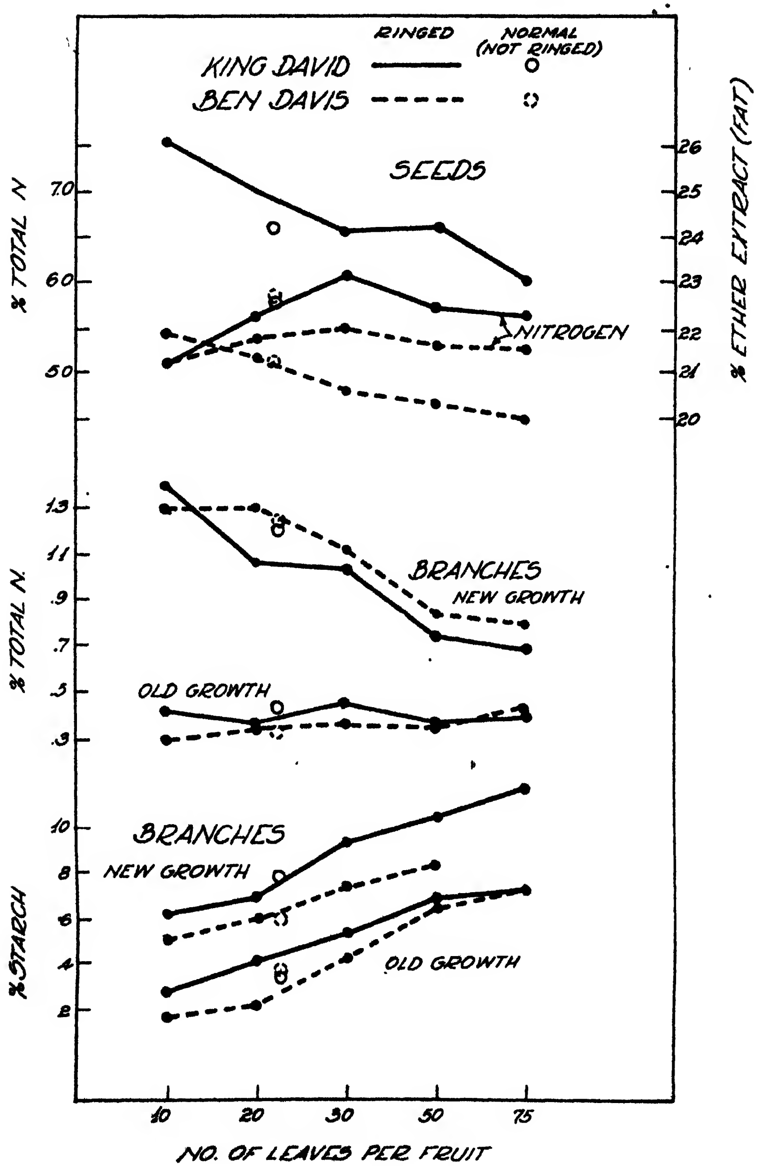

FIG. 1. Relation of leaf number to food reserves in seeds and branches of the apple.

bers of leaves there was a corresponding increase in average diameter and weight of the fruit. This relationship is very precise indeed and extends even to the "normal" fruit grown on branches that were not ringed. The average number of leaves per apple on these check branches was slightly above 20, and the fruit size was also close to that produced experimentally with this number of leaves.

Excepting the 10-leaf group, the average weight of seeds per fruit and the percentage of dry matter in seeds does not indicate any significant variation between the various groups. Seed development, therefore, seems to be remarkably independent of leaf area. Fat (ether extract) concentration in seeds decreased quite consistently with increasing amount of foliage. This most likely is due to an earlier maturity of fruits and seeds when supported by fewer leaves, as was evidenced by a deeper brown color of the seeds and the absence of starch in the flesh of the fruit. It is somewhat difficult to explain the increase in nitrogen concentration in seeds up to and including the 30-leaf group, followed by a slight decrease, assuming that these differences are not due to a possible experimental error.

When ringed branches are adjusted to various leaf and fruit ratios, the older wood showed a conspicuous increase in diameter above the ringed portion with increasing amount of foliage especially beyond 30 leaves. There was a corresponding augmentation in formation of callus tissue at the upper part of the ring. The relative size of buds on branches with a liberal amount of foliage per fruit was also conspicuously greater. These morphological features pointed unmistakably to an increased food supply in these branches. This was confirmed by chemical analyses of both the new and older wood. There was a striking increase in storage of starch, especially in branches with more than 20 leaves per fruit. Evidently, then, the larger the area of foliage per fruit the greater the size of the apple and the more wood growth and carbohydrate (starch) storage in the branches.

The percentage of total nitrogen in the new growth of the twigs decreased with increasing amount of leaves but increased in older wood. Though numerically small, this increase of nitrogen in the older tissues is significant if the total volume of the wood is taken into account. These differences in nitrogen content between the various groups most likely was due to the fact that leaves on branches with more foliage matured considerably earlier and released their nitrogen content sooner. Consequently, there was a greater concentration of nitrogen at the time of harvesting (September) in the new wood of those branches with fewer leaves. This is a typical autumnal migration of nitrogen in the apple tree and has been discussed in detail elsewhere (6). The time of absorption of nitrogen from the leaves, however, seems to have been determined to a large extent by the relative amount of fruit that these branches carried.

From this preliminary study and the work of others, one may draw the following conclusions. The relative amount of foliage on a branch determines to a certain point the size and quality of the apple fruit, but it does not have a corresponding effect on the weight of seeds or their composition. The time of ripening of both the flesh and the seeds seems to be affected by the number of leaves supporting them. The apple fruit, being primarily an organ high in carbohydrates, exerts a dominating metabolic influence and draws heavily on the products of photosynthesis especially during the latter part of its development. If the leaf area exceeds the requirements of the fruit, then a surplus of carbohydrates exists and the vegetative parts of the tree, primarily the spurs and branches, are benefited accordingly. There will be a tendency for greater vegetative development, carbohydrate storage, and increased fruit bud formation. The nitrogen metabolism of fruiting branches is somewhat more complicated. Very likely the apple fruit absorbs the bulk of its nitrogen content during early stages of its development (7), while in the autumn there is a conspicuous migration of nitrogen from the leaves into the spurs and twigs and thence to older wood.

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Ammoniated Phosphorus and Calcium Cyanamide Experiments With Apple Trees

By Fred HofMann, *Virginia Agricultural Experiment Station, Blacksburg, Va.*

In the fall of 1930 and the spring of 1931, several apple orchard experiments were started at the Virginia Agricultural Experiment Station near Blacksburg, Virginia, for the purpose of comparing responses to several fertilizer treatments. Among these were fall and spring applications of Calcium Cyanamide[1] and spring applications of Ammoniated Phosphorus. Several of the results which proved to be of some interest are, herewith, briefly presented.

These experiments were conducted in a 20-year-old York Imperial, Stayman Winesap, and Grimes Golden apple orchard. The soil in this orchard is described as a Clarksville gravelly silt loam. It is very cherty, shows a pH reading of about 6, and is below the average in general fertility. It is particularly low in phosphorus. The sub-soil, composed mostly of a tight stiff clay, is seldom penetrated to depth of more than 2 feet. At the time of the experiment the trees were low in vigor and small for their age as compared to other trees planted in the same year in this general vicinity. These trees are planted 25 feet apart which no doubt in a large measure prevented more vigorous growth.

The different fertilizer treatments were applied to separate rows of 50 trees each. Every row is planted to York Imperial, Stayman Winesap, and Grimes Golden, successively. One row received 5 pounds of Calcium Cyanamide per tree in spring; a second 10 pounds; a third, 15; a fourth, 5 in fall; and a fifth, 10 in fall. A sixth row received 13 pounds of a 16–20 Ammoniated Phosphorus application in spring. On a nitrogen basis this amount is equivalent to 10 pounds of Calcium Cyanamide. The purpose of using the larger amounts of these fertilizers was to study certain toxic effects as will be brought out later. The first applications for fall were made in 1930 and those for spring in 1931. The results that are presented in this paper include the fall applications of 1930, 1931, and 1932, and those of spring in 1931 and 1932.

Results

All of the applications of Calcium Cyanamide killed out the ground growth cover under the trees. There was no observable difference in this regard between the fall and spring applications. Among the plants that were killed out are plantain, dandelion, lespedeza, blue grass, bromesedge, orchard grass, and honeysuckle. In all these cases where Calcium Cyanamide was used, the area under

[1]Capital letters are used for the commercial form and small letters for the chemical form.

the trees remained bare except under the 5-pound fall applications which allowed an occasional sprinkle of growth by the middle of June.

The trees that received this fertilizer had foliage that was greener than in the unfertilized trees. Applications exceeding 5 pounds per tree, whether they were made in fall or spring showed marginal leaf scorch in August of 1932. The severest scorching was found in the spring applications of 10 and 15 pounds per tree.

Under the trees that received 13 pounds of Ammoniated Phosphorus, there was a noticeable response in the ground cover. By the middle of May following the first application made in March, the ground cover under the trees receiving this treatment was three times as high as the growth under the unfertilized trees and produced a dense mat of sod. It may be of interest to point out that although the amount of Ammoniated Phosphorus was over 2½ times the 5-pound Calcium Cyanamide applications, the ground

TABLE I—COMPARISON OF RESPONSES OF APPLE TREES TO CALCIUM CYANAMIDE AMMONIATED PHOSPHORUS (PRICE ORCHARD—BLACKSBURG, VA., 1932)

Treatment per Tree (Pounds)	Average Terminal Growth per Tree (Inches)	Average Circumference Increase of Trunk (Inches)	Average Yield of Fruit per Tree (Pounds)
Calcium Cyanamide—5, fall	4.33	1.17	31.5
Calcium Cyanamide—10, fall	2.78	1.22	37
Calcium Cyanamide—5, spring	2.50	.93	25.5
Calcium Cyanamide—10, spring	2.36	1.00	52.5
Calcium Cyanamide—15, spring	2.51	.73	35
Ammoniated Phosphorus—13, spring	5.75	1.24	208
Unfertilized—None	1.65	.83	12.5

cover growth was stimulated by the former but killed out by the latter. Computed upon the basis of the average amount of area covered by the different fertilizers used under each tree in these experiments, Calcium Cyanamide at the rate of 1 pound to 15 square feet caused the ground cover to be killed out. No such toxic effects were observed with Ammoniated Phosphorus.

The trees that received Ammoniated Phosphorus showed relatively heavier foliage as well as stronger wood growth as early as the middle of May following the first application after the experiment was started. The trees continued to be in a condition of vigorous growth throughout the summer and late into the fall. After the leaf drop, the size of the fruit buds was observed to be larger than those in the other treatments. Growth measurements and yields were also decidedly greater. See Table I.

In the fall of 1932, the average yield per tree for this treatment was 208 pounds of fruit; the average terminal growth, 5.75 inches; and the circumference increase of the trunk, 1.24 inches. The unfertilized trees gave a yield of 12.5 pounds of fruit, 1.65 inches terminal growth, and a trunk circumference increase of .83 inches. The trees receiving 10 pounds of Calcium Cyanamide in the fall gave a yield of 37 pounds of fruit, 2.78 inches of terminal growth,

and a trunk circumference increase of 1.22 inches. Very likely more vigorous trees will not respond to a similar degree.

Results with Acid Phosphate and Calcium Cyanamide Mixtures

These experiments suggested an inquiry into some of the effects that would be secured with Acid Phosphate and Calcium Cyanamide mixtures when applied to apple trees. It appeared that some of the less desirable properties of Calcium Cyanamide could be modified to some degree. It has been known for many years that Calcium Cyanamide is not stable in aqueous solutions, but immediately hydrolyzes to acid calcium cyanamide and calcium hydroxide. Experiments show that when Calcium Cyanamide is mixed with moist soil, a variety of substances is produced. Among these are calcium cyanamide, calcium hydroxide, ammonia and urea. In concentrated solutions a basic salt ultimately separates out in needles with free cyanamide. Of these products formed from Calcium Cyanamide, free cyanamide has the more caustic and toxic effects upon plant tissue. The effect of this chemical is such that it can also kill seeds while they are still dormant. A product known as dicyanodiamide is polymerized almost quantitatively when free cyanamide is treated with moderately alkaline solutions at higher temperatures. Dicyanodiamide does not have the causticity and toxicity which is found in Calcium Cyanamide under certain conditions. Nevertheless, the nitrogen in dicyanodiamide is in a form that is not so quickly available to apple trees as when in the form of urea.

In mixtures of Calcium Cyanamide and Acid Phosphate, there are differences in the proportion of dicyanodiamide to urea. Where the Acid Phosphate is less than 25 per cent or above 50 per cent of the mixture with Calcium Cyanamide, a higher proportion of urea is produced. Several experiments carried on at this station indicate that such mixtures may be of some value. The mixtures per tree applied in the fall with 5 pounds of Calcium Cyanamide constant are as follows: 5 pounds of Acid Phosphate for a 50 per cent, 15 pounds for a 75 per cent, and 1½ pounds for a 25 per cent mixture. The only report that can be made at this time for Acid Phosphate and Calcium Cyanamide mixtures is that they produce a better ground cover growth than where Calcium Cyanamide alone has been applied. From these results, there is a clear indication to the writer that some benefits may be secured with such mixtures.

Artificial Culture of Abortive Cherry Embryos

By H. B. Tukey, *Experiment Station, Geneva, N. Y.*

ABSTRACT

This material has been published in the Botanical Gazette 94: 433–468, 1933, and in the Journal of Heredity 24: 7–12, 1933.

VARIETIES of stone fruits, mainly of the genus Prunus, which ripen the fruit early, regularly fail to produce viable seed. Late-ripening varieties, however, produce viable seed. This statement applies to both sweet and sour cherries (*Prunus avium* and *P. cerasus*), to the European plum (*P. domestica*), and to the peach (*P. persica*). Normally there are three stages of pericarp development in the cherry, namely, (1) rapid development immediately following full bloom; (2) retarded development of 14 to 16 days beginning about 17 days after full bloom; (3) a second rapid development to maturity. The nucellus and integuments reach nearly maximum size early in the development of the fruit. The embryo, however, remains small for about 21 days following fertilization. It then makes a sudden and rapid increase in size and continues to the development of viable seed.

A critical anatomical and cytological study of the development of a variety which normally produces no viable seed in comparison with a variety which normally produces viable seed indicates no apparent difference between the development of the two from the period when examinations were begun, namely, 51 days before full bloom, until the nucellus and integuments have attained nearly maximum size and when the fleshy pericarp is in its second period of rapid development. At this time the rapid development of the embryo of early-ripening varieties occurs and is almost coincident with the second period of rapid development of the pericarp. In the case of the late-ripening varieties, on the other hand, embryo development is well advanced before the second period of rapid pericarp development begins. The embryos in the early-ripening varieties subsequently abort, whereas the embryos of the late-ripening varieties proceed to full development and enter a period of dormancy.

The situation suggests the possibility of removal of the abortive embryos before they have disintegrated, and culturing them. Using a medium containing nitrogen and a carbohydrate and in the presence of light, the cotyledons develop chlorophyl and the embryo develops normally. By this method it has been possible to develop seedlings from embryos which normally have aborted and disintegrated.

Some interesting problems are presented by these facts, namely, though a normal cherry seed requires an after-ripening period of about 4 months at a temperature of 40 degrees F, abortive embryos will germinate immediately, apparently having never entered dor-

mancy. It would seem that here would be a good place to study the mechanics of dormancy. Another point of practical significance is that in the breeding of early-ripening varieties of stone fruits it has heretofore been impossible to secure viable seed when early-ripening varieties were used as female parents. By culturing embryos artificially, further progress might be made in breeding for early-ripening characters.

Finally, the question is raised as to what really constitutes sterility, inasmuch as a variety of cherry which has heretofore been classed as sterile, may, under proper nutritive conditions, produce seedlings.

Utilization of Nitrogen, Phosphorus, and Potassium by Pyrus Malus Subjected to Differential Treatment With Nutrient Salts

By WALTER THOMAS, *Pennsylvania State College, State College, Pa.*

ABSTRACT

This paper will appear in the Journal of Agricultural Research.

Growth-Differentiation Balance vs. Carbohydrate-Nitrogen Ratio

By W. E. LOOMIS, *Iowa State College, Ames, Ia.*

IT has been nearly 30 years since Klebs (4) published his "Willkürliche Entwickelungsänderungen bei Pflanzen," in which he summarized his earlier work on the behavior of plants in varying environments, and proposed the principle that the course of plant development is determined by internal conditions, but that these internal conditions may in turn be altered by external factors. Klebs' proposal remained largely a matter of academic interest until Kraus and Kraybill (5) showed the applicability of his principle to the control of fruiting in commercial crops. It is safe to venture that nothing has more influenced horticultural investigations of the last decade than Oregon Bulletin No. 149. On page six of this bulletin moisture, mineral nutrients, and available carbohydrates as well as total nitrogen and total carbohydrates are spoken of as factors affecting the fruiting responses of plants.

The relatively great importance of nitrogen in the field fertilization of perennial fruit plants has led some workers to the assumption that the mathematical ratio of total nitrogen to total carbohydrates is a determining factor in plant development although the experiments of Work (10), Nightingale (7), Potter and Phillips (8), and others clearly indicate that there is no simple or consistent relationship between the ratio of nitrogen to carbohydrates and the growth response of the plant. On the other hand the experience of growers and research workers is adequate evidence that there is a relationship between the nitrogen fertilization of an apple orchard and its fruiting.

The suggestion is here advanced that the unquestioned progress which has resulted from the use of the carbohydrate-nitrogen concept in horticulture has been due to its inclusion of two of the important Growth-Differentiation Balance factors, and that its failures have been due to the omission of other essential factors.

THE GROWTH-DIFFERENTIATION CONCEPT

Following common practice we divide the development of plants into three, overlapping, but reasonably distinct, phases, namely, (1) the cell division phase, (2) the cell enlargement phase, and (3) the phase of maturation or cell differentiation. The first two of these can be grouped together as increase in size, or growth. Differentiation, we are accustomed to think of as morphological in nature, but our knowledge of the general course of plant metabolism and of the specific responses of plants to varying conditions, makes it equally logical to consider observed morphological changes as an expression of pre-existing chemical conditions within the cell or tissue. For the purposes of the Growth-Differentiation Balance

we define differentiation as the sum of the chemical changes which occur in maturing cells, and of the morphological changes which arise as the result of these chemical conditions. Qualitatively, differentiation is dependent upon genetic factors, but wide quantitative variations are possible.

The recent work of Priestley (9) and others on the growth of plants makes it possible to classify some of the more important internal factors affecting plant development. A tentative classification of factors affecting the Growth-Differentiation Balance is given in the following tabulation:

Factors Affecting the Development of Plants

I. Growth

A. Cell Division

1. Protoplasm. The building of new protoplasts in cell division depends upon (a) sugars; (b) nitrogen; (c) sulfur and phosphorus, and probably magnesium, potassium, iron, boron, and other nutrients; (d) the necessary enzyme complex; and (e) in some plants, apparently, upon radiation factors not covered in the usual concept of photosynthesis.
2. Moisture. According to Priestley (9), cell division is dependent upon a liberal moisture supply at the growing point. Drought limits growth directly and moisture is a major factor in the growth balance.
3. Temperature. Cell division involves many biochemical changes which are accelerated by rising temperatures over a limited range and inhibited by excessively high temperature.
4. Oxygen. Available oxygen is essential but its concentration apparently need not be high.

B. Cell Enlargement

1. Moisture. The enlargement of the newly divided, plastic walled cells appears to depend almost alone on available moisture. Higher osmotic values will increase the force with which water is absorbed, but they commonly mean higher sugars and a rapid thickening and decrease in the extensibility of the cell wall.

II. Differentiation

1. Sugars. The maturation of enlarged cells is primarily a series of chemical processes for which available carbohydrates (probably sugars) serve as the raw material. These changes may be in (a) the cell wall, as lignification, suberization, etc.; (b) the chemical composition of the cell contents, as the accumulation of alkaloids, essential oils, gums, etc.; (c) the structure of the protoplast, as seems probable in cold and drought resistance and possible in dormancy; or, (d) the type of development, as the changes from vegetative buds to flower buds or from somatic cells to spore mother cells.
2. Temperature is obviously important in a process as dependent upon chemical reactions as is differentiation.

If we omit oxygen, which is seldom directly limiting for plant growth, and temperature, which accelerates reactions on both sides of the balance, growth is found to be dependent upon available moisture and the synthesis of protoplasm, and differentiation dependent upon available carbohydrates. The carbohydrate-nitrogen balance has been modified by raising the water supply from an incidental to a major and frequently determining factor, and by

including with nitrogen all of the other complex, and in many cases unknown, factors which affect the synthesis of protoplasm.

Kraus and Kraybill (5) suggest, and Work (10) and Potter and Phillips (8) emphasize, that accumulations of insoluble carbohydrates are a better measure of the past history of the plant than of its present responses. It is felt that if analyses could be made at the instant of the initiation of a particular carbohydrate response that soluble materials and probably sugars would be the active substances. For this reason sugars rather than total carbohydrates are given as the important factor affecting differentiation.

Applications of the Growth-Differentiation Balance

If plants are grown at moderately high temperatures with liberal supplies of moisture and nutrients and with favorable illumination, the rapid vegetative growth obtained is characteristic of the Class 2 plants of Kraus and Kraybill (5). Under these conditions the sugars produced by the plant are used in the synthesis of proteins and to supply the high energy requirements of active meristematic tissues. Differentiation approaches a minimum for the species, and flowering may be suppressed. At the same time the stems produced are succulent and their cell walls thin and poorly lignified. The leaves are large with little or no cuticle and with poorly developed conducting tissues. The accumulation of gums, alkaloids, or essential oils, etc., is reduced to a minimum and the plant is non-dormant and non-hardy to cold and drought. All of these conditions are, according to our definition, expressions of the dominance of growth over differentiation.

If the growth of such a rapidly growing and relatively undifferentiated plant is checked in a manner which does not appreciably reduce the photosynthetic activity of the plant, for example by gradually reducing the moisture or nutrient supply available to the top, the carbohydrates formerly used in growth now accumulate and serve at once as the stimulus and as raw materials for differentiation. Cuticle and cork develop, cell walls are thickened, fibers and conducting elements are more abundant in the new tissues, resins, gums, alkaloids, etc., accumulate, the protoplasts become more resistant to drying and cold, and flowering may result.

Numberless examples could be given to illustrate differentiation resulting from increased carbohydrate concentrations. The best tobacco for cigar wrappers is grown under shade in humid climates with minimum differentiation, but the best tobacco for insecticides is grown in hot, dry sections with brilliant sunshine. Rubber and camphor producers choose sections in which the climate alternates from conditions favorable to growth and the production of a large photosynthetic area to conditions which favor the accumulation of sugars and the differentiation of the commercial product desired. Plants grown in bright sun on dry soil are more differentiated than shade plants growing in moist soil. Plants whose roots are injured

may flower heavily but plants which have lost portions of their photosynthetic area commonly show a growth response, and so on.

An interesting and important subphase of the general G/D Balance is the root-top ratio. Although growth and differentiation in the roots is not essentially different from the same processes in the top, the interdependence of the roots and tops for their supplies of materials necessary for growth has been shown by Chandler (1) and by Loomis (6) to result in an equilibrium between the growth of these organs. When moisture and nutrient conditions are favorable for top growth the organic foods are used in this process and root development suffers. With differentiation conditions and sugar accumulations in the top, as the result perhaps of dry or infertile soil or of deficient root development, organic materials are translocated to the roots, and root development is stimulated.

The Growth-Differentiation Balance and Reproduction

Within our definition of differentiation, sexual reproduction in seed plants consists of alternating cycles of differentiation and growth. The flower bud is initiated by differentiation; it grows into the flower. The gametes are differentiated; the fruit and fertilized ovules grow. With this rapid swing from one type of development to the other it is commonly impracticable to alternate the G/D Balance and we compromise by growing fruiting plants under intermediate conditions so that differentiation and growth can occur simultaneously; Class 3 of Kraus and Kraybill (5). The differentiation nature of flower bud initiation and the importance of relatively high sugars at this point is generally recognized. The work of Howlett (3) and common experience in orchard practice indicates the importance of protoplasm synthesis and water supply in flower and fruit growth.

The Growth-Differentiation Balance and Hardiness

The recent work of Graber (2) and his associates indicates that winter hardiness is dependent upon a high carbohydrate supply in the tissues and suggests that hardiness is a differentiation process. In a private communication Dr. J. N. Martin states that the appearance of the protoplasts in hardened alfalfa and sweet clover plants is distinctly different from that of the unhardened plants of the same variety. Future research may show that hardiness is the result of a structural differentiation of the protoplast which makes it more resistant to precipitation, such differentiation being dependent upon and in part initiated by a high sugar concentration in the tissues.

The Growth-Differentiation Balance and Photoperiodism

Our knowledge of the nature of the photoperiod response is so meager as to make generalizations on the topic somewhat danger-

ous, but the observations of Nightingale (7) that nitrate and starch accumulate together in short-day, flowering, salvia plants suggests an explanation of this interesting and important phenomena. Nightingale's data can be interpreted as indicating that the synthesis of protoplasm in short-day plants is dependent upon the length of the daily illumination period. Under short-day conditions protoplasm synthesis, and therefore growth, is checked, carbohydrates accumulate in spite of the short period for photosynthesis, and differentiation results. The nature of the photochemical reactions involved can of course be determined only by further research.

In long-day plants these factors necessary for protoplasm synthesis may be produced more rapidly so that long light exposure which reduces available moisture and increases photosynthesis is the factor checking growth and resulting in the sugar accumulation necessary for flower bud differentiation.

Summary

Plant development is divided into two phases, namely, growth and differentiation; and variations in the form, chemical composition, and growth behavior of a genotype are explained on the basis of variations in the Growth-Differentiation Balance within the plant.

Growth is defined as increase in size due to cell division and cell enlargement, and differentiation as the sum of the chemical and morphological changes which start during cell enlargement and end with the death of the cell.

At moderately high temperatures growth in plants is dependent upon the moisture supply at the growing point and upon the supply of synthesizable, protoplasm building materials. Differentiation, under the same conditions, is assumed to be dependent upon the sugar concentration of the cell sap of the differentiating cells or upon substances closely correlated with this concentration.

Growth-Differentiation Balance differs from the Carbohydrate-Nitrogen Balance as commonly stated in (a) assigning an independent and major role to moisture, (b) including with nitrogen the other equally essential if not so commonly limiting factors concerned in the synthesis of protoplasm, (c) recognizing the effects of temperature, and (d) emphasizing the importance of active carbohydrates as opposed to storage forms.

The concept of Growth-Differentiation Balance is not offered as a complete and final statement of the developmental processes in plants, but as a convenient and simplified scheme for predicting or explaining plant behavior.

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Accumulation of Carbohydrates in Apple Foliage, Bark, and Wood as Influenced by Moisture Supply

By J. R. MAGNESS, L. O. REGEIMBAL, and E. S. DEGMAN, *U. S. Department of Agriculture, Washington, D. C.*

DURING the past growing season an unusual opportunity was afforded to make certain studies in the functioning of apple trees under conditions of reduced moisture supply. In connection with the investigational work of the Department of Agriculture on moisture relationships in the orchards of the Potomac Valley of western Maryland, plots were established in the spring of 1932 in a block of Delicious growing on a moderately shallow shale soil near Hancock, Maryland. The trees had received uniform good orchard treatment prior to 1932. Trees in the plots selected all carried a heavy crop of fruit. Four uniform Delicious trees were selected as record trees in a plot which would receive sufficient irrigation throughout the season that the trees would not suffer for water at any time. A comparable set of trees received natural rainfall. The plots were cultivated in the fall of 1931, and seeded to wheat and clover. The trees would be considered moderately vigorous for eastern conditions.

There was a fair distribution of rainfall throughout the spring and early summer. Consequently, during the growth period of the trees sufficient moisture was available and the growth condition and foliage on the wet and dry plots were approximately similar.

Beginning in early July the soil moisture in the non-irrigated plots was reduced to the point where growth of fruit and functioning of the trees began to be decreased as a result of the water shortage. By August 11 the stomata in the foliage of the trees on the dry plots were remaining open only approximately half as long as those on the trees which received irrigation. During the week of August 8–15 the average growth increment of the apples on the irrigated plots was 11 cc, while that on the dry plots was 7.9 cc. Thus the fruit during this period grew almost 40 per cent faster on the irrigated than on the dry plot. On August 11, the date on which detailed leaf samples for chemical study were taken, the average moisture condition in the surface 2 feet of soil in the dry plot was approaching the wilting percentage, though a light shower the previous day (Aug. 10) had moistened the surface. The irrigated plots averaged 3 to 4 per cent more moisture in the surface 2 feet than the dry plot.

On August 11, a series of leaf samples from the trees on the wet and dry plots were taken at intervals throughout the day. Only well developed leaves from approximately the middle portions of the new growth were selected. Samples were taken uniformly from about the periphery of the four trees in each plot. Samples were immediately weighed in the field and placed in an ice-calcium-

chloride bath for freezing. They were held in a frozen condition until ready for analysis.

As the authors were particularly interested in the concentration of carbohydrates in the juice of the leaf, the leaf samples after freezing were pressed under pressure of approximately 40,000 pounds per square inch. The juice secured was weighed, the freezing point depression determined, and the juice preserved in alcohol for sugar analysis. In all cases the freezing point depression paralleled the sugar content of the juice although not more than approximately 25 per cent of the freezing point depression could be accounted for on the basis of sugar content. Detailed data for freezing point depression are not given.

The leaf residue following pressing was thoroughly extracted with alcohol, each sample being given at least 25 hours in a Soxhlet extractor to insure complete removal of the sugars. Starches were determined in this residue by the saliva digestion method. Dry weights were determined on duplicate samples.

The data resulting from the leaf analyses are shown graphically in Fig. 1 together with a detailed curve of the stomatal behavior of the leaves recorded in the field according to the method of Magness and Furr (1). Temperature and humidity throughout the day are also recorded.

Stomata had started to open on both the irrigated and dry plots before the first readings were taken. It is apparent, however, that throughout the day approximately twice as many stomata were open on the irrigated plot as on the dry plot. The day was moderately cool with fairly high humidity, which accounts for some stomatal opening occurring throughout the day on both plots.

Leaves lost moisture rapidly from daylight until 11 A. M., at which time the dry weight of the leaves was highest. With the closing of most of the stomata, and under the relatively low evaporation conditions, the leaves increased slightly in moisture throughout the remainder of the day.

Analyses for total sugar in the pressed juice indicate a fairly steady increase in sugar content in the foliage until about 1 P. M., after which hour the sugar content remained fairly steady, showing some drop by 7:45 P. M., at which time it was practically dark. The starch content in the leaves increased from approximately 0.20 per cent in the morning to a maximum of 0.58 per cent in the irrigated leaves at 11:20 A. M. and 0.50 per cent in the dry leaves at 1:30 P. M.

While the differences in sugar and starch content of the irrigated and of the dry leaves are small, they are remarkably consistent throughout the day. A higher content of both sugar and starch was found in the irrigated leaves.

A second series of samples from the same trees was taken on September 15. Soil moisture in the dry plot on that date was close to the wilting percentage in the surface 2 feet. During the period

September 12–16 the growth increment of typical apples on the irrigated plot averaged 1.80 cc per day, while that of the fruit on the dry plot averaged .92 cc per day. Thus the fruit on the irrigated plot was growing at approximately double the rate of that on the dry plot on September 15 when these samples were taken. The data secured on this date are shown in Fig. 2.

In general the results obtained from the sampling on September 15, approximately 10 days prior to harvest time, were similar to those obtained 5 weeks earlier. Stomatal opening was somewhat less on the latter date, due to the fact that the soil was possibly

TABLE I—SUGAR AND STARCH CONTENT OF BARK, WOOD, AND FRUIT FROM DRY AND IRRIGATED DELICIOUS APPLE TREES SAMPLED SEPTEMBER 15, 1932, HANCOCK, MARYLAND

Tissue	Time Sampled	Treatment	Total Dry Matter (Per cent)	Total Sugar in Juice (Per cent)	Starch (Per cent Wet Weight)
Bark.......	6:30 A.M.	Irrigated	45.8	2.36	1.88
Bark.	6:30 A.M.	Dry	46.0	2.65	1.41
Bark.......	3:30 P.M.	Irrigated	49.0	2.79	1.96
Bark..	3:30 P.M.	Dry	51.4	3.26	1.30
Wood	6:30 A.M.	Irrigated	52.9	0.42	2.02
Wood	6:30 A.M.	Dry	54.7	0.71	1.57
Wood......	3:30 P.M.	Irrigated	54.1	0.45	1.90
Wood......	3:30 P.M.	Dry	53.3	0.93	1.59
Fruit.......	6:30 A.M.	Irrigated	14.7	9.40	3.10
Fruit.......	6:30 A.M.	Dry	17.2	9.96	3.47
Fruit.......	3:30 P.M.	Irrigated	14.4	8.52	3.97
Fruit..	3:30 P.M.	Dry	16.9	10.05	3.43

somewhat drier and the humidity somewhat lower. In general the results for the leaf analyses closely correspond with results obtained at the earlier sampling date.

On September 15, samples of bark, wood, and fruit tissues were also taken. Branches approximately ¾ inch in diameter were selected which carried a crop representative of that on the tree as a whole. The leaves were immediately stripped from these branches. They were taken to a field laboratory nearby where duplicate 50-gram samples of bark, wood, and fruit were prepared as quickly as possible. The bark was handled under moist towels to prevent drying during the sampling. Bark and wood samples used were taken from branches from ¼ to ½ inch in diameter. Fruit samples were made up of sections from approximately 30 representative fruits.

The wood, bark, and fruit samples were handled exactly as were the leaf samples. The results of the analyses of wood, fruit and bark are shown in Table I.

A study of the data in Table I indicates that the bark lost water during the day in approximately the same proportion as did the

leaves. On the other hand, the wood from the same samples remained practically unchanged in moisture content. In total sugar the irrigated trees were lower than the corresponding dry trees in all the samples in the bark, wood and fruit. Eighty to ninety per cent of this total sugar was in the free reducing form.

On the other hand, the starch content of the wood and bark of the irrigated trees was in every case markedly higher than that of the corresponding dry trees. These results would appear to indicate that under dry conditions the sugar-starch ratio in the storage organs of the tree is modified so that a relatively larger proportion of the carbohydrate is in the form of sugars and a relatively smaller proportion is in the form of starch. Thus the effect of drouth may be somewhat similar to the effect of cold weather in causing a greater proportion of the carbohydrate to be in the soluble form.

Discussion

The data shown in Figs. 1 and 2 indicate that the controlling factor in stomatal closing in apples is the amount of moisture

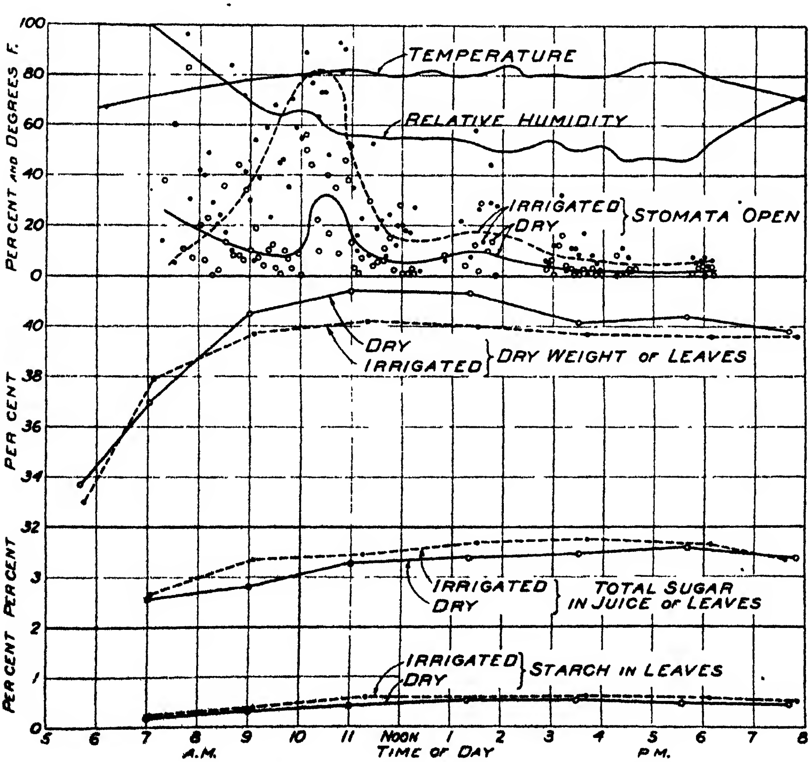

Fig. 1. Percentage of stomata open and the chemical composition of Delicious apple foliage from irrigated and non-irrigated trees. Samples taken throughout the day of August 11, 1932.

present in the leaf rather than the concentration of sugars or starch. Throughout the day the sugar concentration in the juice of the leaves of the irrigated trees was higher than that of the leaves of

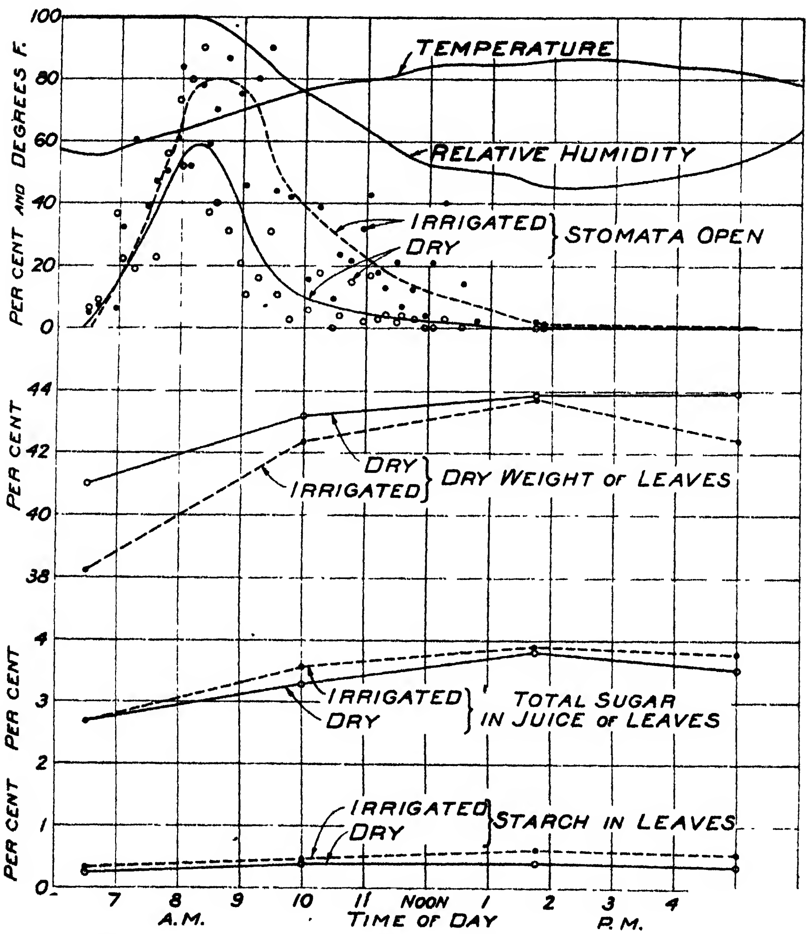

FIG. 2. Percentage of stomata open and the chemical composition of Delicious apple foliage from irrigated and non-irrigated trees. Samples taken throughout the day of September 15, 1932.

the dry trees. The stomata remained open longer on the irrigated plots. The closing of the stomata appears from these data to be an important factor in limiting leaf evaporation. Following the closing of the stomata the moisture content of the leaf remained steady or increased during the remainder of the day. On the other hand, while the stomata were open the leaves apparently lost water much more rapidly than it was supplied by the tree. In other experi-

mental plots in still drier condition, definitely wilted leaves continued to lose water throughout the day, even though the stomata were entirely closed.

A theoretical calculation indicates that the foliage of apple trees forms dry matter equal to approximately 2 per cent of the wet weight of the foliage per day under average growing conditions. In the analyses here reported the accumulation of carbohydrates in the leaves during the day amounts to approximately 1.25 per cent when a correction is made for the water loss from the leaf. There is every reason to believe that translocation of these materials out of the leaf occurs during the day as well as at night and that this translocation is responsible for the fact that greater accumulations of carbohydrates in the leaves during the day were not found. In view of the more rapid utilization of the carbohydrates in fruit growth on the irrigated trees, it is probable that this translocation is more rapid from the leaves of these trees.

The rapid loss of moisture from the bark as well as from the leaves raises the question as to how the bark of the tree is supplied with water. While the evidence here is rather meager, it suggests a very close correlation between moisture supply in the leaves and in the bark and suggests the possibility that the water in the bark may be supplied through the leaves rather than being supplied from the wood direct.

Of particular importance from the standpoint of effect on the trees is the apparent change in sugar-starch ratio under conditions of decreased moisture supply. It is a widely prevailing idea which appears to be supported by some evidence that, in general, drouth conditions during the summer tend to increase fruit bud formation for the following year. On the other hand, the evidence presented here indicates that one effect of a drouth condition is to decrease carbohydrate formation in the leaves of the tree. Since an accumulation of carbohydrates appears clearly associated with fruit bud formation in horticultural plants, this apparent effect of drouth on fruit bud formation would appear difficult of explanation.

It seems certain that if carbohydrate supply is associated with fruit bud formation, the effective carbohydrates would be those in solution, in other words, the sugars rather than starch. It is hard to understand how an inert material such as starch could directly affect fruit bud formation except through its possible association with the soluble carbohydrates. If the sugar-starch ratio in the plant is increased under drouth conditions, however, as appears from these data, the effect of drouth conditions on fruit bud formation could be readily interpreted.

In this connection, the great difference between the sugar content of the pressed juice from the bark and from adjacent wood needs emphasis. Concentration of sugars in the juice of the bark is from three to six times as high as in that of the wood. In analyzing plant tissues, particularly from the standpoint of correlating the

response of the plant to chemical composition, the separation of bark and wood appears essential if significant results are to be obtained.

The evidence presented indicates that carbohydrate synthesis in apple foliage is reduced under conditions of moisture shortage, correlated with reduced stomatal opening. Under these conditions the starch present in storage tissues is reduced, but the sugar content of the plant juices is increased.

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Some Observations on the Assimilation of Ammonium and Nitrate Nitrogen in Some Horticultural Plants

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Abstract

This paper will appear in the Journal of Plant Physiology.

It is necessary that the limitations of the use of nitrogenous salts be determined before a fair comparison of their relative merits as plant nutrients can be made. Any of the following comparisons made between ammonium and nitrate nitrogen are on the assumption that the respective salts are supplied to the plants at the pH values of the nutrient medium or soil which are optimum for the assimilation of the particular ion under consideration.

The hydrogen-ion concentration of the nutrient medium directly or indirectly had a controlling influence on the assimilation, particularly of the ammonium ion. The nitrate ion was assimilated most satisfactorily in tomato and apple when absorbed from an acid nutrient solution of approximately pH 4.0. The ammonium ion was assimilated most satisfactorily when absorbed from a nutrient solution having a constant pH value of pH 5.0 to 6.5, varying somewhat for the variety.

Ammonium ions were immediately absorbed by plants without further change and were assimilated (synthesized to amino acids and other organic nitrogenous materials) directly and more rapidly than the nitrate ion.

Nitrate ions were apparently absorbed, reduced to nitrite, and finally ammonium ions by the action of reducase (nitrate reducing material in the plant). The ammonium ion was, however, assimilated directly and as rapidly as it was absorbed, whereas the nitrate ion usually tended to accumulate, at least partly, because of limited reducase activity under certain external and internal conditions. The ammonum ion, therefore, was more quickly available for the synthesis of amino acids. The ammonium ion did not accumulate in plant tissue unless the plant could not assimilate this form of nitrogen.

The volume of growth obtained from nitrate and ammonium depended on the concentration of the nitrogenous salt in the nutrient solution, and available carbohydrates.

There was a direct correlation between the concentration of nitrate nitrogen and the volume of growth produced if the plant was actively reducing nitrate. Plants required a much lower concentration of ammonium than nitrate nitrogen in the nutrient solution to produce an equal volume of growth.

Plants containing a large amount of available carbohydrates assimilated ammonium much more rapidly than those containing a comparatively small supply of available carbohydrates. Tomato and apple grown with ammonium contained a much higher concentration

of soluble organic nitrogen than those supplied with an equal quantity of nitrate. There was a direct correlation between the concentration of ammonium in the nutrient solution and the amount of soluble organic nitrogen elaborated by the tomato and apple.

Tomato and apple growing on soil, containing ammonium and nitrate ions, absorbed both ions. Whether they assimilated both ions depended partly on the pH of the soil. On acid soils having a pH of 4.0, plants tended to accumulate ammonium and assimilate nitrate ions. On neutral or slightly alkaline soils, plants tended to accumulate nitrate ions and assimilate ammonium. When ammonium salts were applied to soil cultures, some of the ammonium ions were oxidized to nitric acid, and were absorbed by plants as nitrate ions.

In general ammonium and nitrate salts produced equally good growth, provided their limitations were recognized. Whether nitrates were reduced in the plant to ammonium nitrogen or the nitrogenous nutrient was supplied directly as ammonium the quality of organic nitrogen in plants grown with salts from either group was similar where the total concentration of elaborated nitrogen was the same.

In field experiments where comparisons are made between salts of either group, comparative data may be of little value, unless the condition of the soil and quantity of nitrogenous ions absorbed and assimilated by the plants supplied with salts from either group are very specifically evaluated. If salts from the two groups are used under optimum conditions for each the only advantage one salt will have over the other would be brought about as a secondary effect by the ion with which the nitrate or ammonium ion is associated.

Little-Leaf or Rosette of Fruit Trees, II: Effect of Zinc and Other Treatments

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LAST year (3) we described this disease in some detail and reported complete recovery following application of an impure form of ferrous sulphate rich in zinc but apparent failure of chemically pure ferrous sulphate to cause any improvement. We reported also that two trees severely injured by little-leaf, treated in August, 1930, with zinc sulphate through the soil, showed great improvement during the summer of 1931. During the summer of 1932, the trees treated with chemically pure ferrous sulphate continued to show no improvement; the two trees that had been treated with zinc sulphate were completely free of little-leaf and healthy.

During the winter and spring of 1931–32, many trees were treated with zinc compounds and some with other substances.

Soil Treatments with Zinc Compounds

Trees were treated in a number of different soil types. The results were in approximate agreement with those following treatment with the impure ferrous sulphate rich in zinc: trees having little-leaf bad enough for leaves on the summer shoots to be mottled began to show improvement by about June 1, earlier with heavy treatments. There was evidence that the soil may have a high fixing power for zinc and may reduce the amount reaching the roots. A number of the soils were therefore studied for such fixing power.

A given dry weight of the soil concerned was mixed thoroughly with an equal weight of water to which had been added a known amount of zinc sulphate. After 2 hours this was filtered on a Buchner funnel and the filtrate tested for zinc. If little or none was found, another lot of the same soil was mixed with water containing a larger percentage of zinc, but if there was a considerable amount of zinc in the filtrate the soil was washed with water until very little zinc was carried through. The amount of zinc in the entire filtrate was then determined by ferrocyanide titration. The amount originally mixed with the soil less the amount in the filtrate represents the amount held in the soil. The fixing power could be reduced by igniting or treating with H_2O_2 to remove organic matter; that of an alkaline soil could be greatly reduced by treating it with acid. Clay, organic matter, and salts, seem to be most important in fixing zinc. In all our experiments when zinc sulphate was applied alone, on the surface of the soil, more was required to correct a tree than would be contained in the amount of impure ferrous sulphate necessary to correct it. Ferrous sulphate may reduce the fixing of zinc in a soil by its acid effect or by replacement.

In Table I are shown the results concerning soil fixing power and the responses of trees to zinc treatments. The material applied was spread around the trees from the trunks outward 1 to 9 feet, "R" designating the radius. Thus "R 9 ft" means the material was spread over all the soil within a radius of 9 feet from the trunk; "ring 3 ft" means it was spread in a narrow band 3 feet from the trunk. Sometimes it was applied in basins around the trunk, always deep enough to expose some of the roots. Except when chemically pure zinc sulphate was being tested, the grade used was the cheapest we could obtain and is designated "Com" when being compared with C.P. Except where otherwise indicated, application was on the surface of the soil.

With the zinc sulphate, the response appeared earlier in the season and the improvement was more complete in the first summer if quantities used were considerably larger than would be necessary to bring complete correction in the second summer. We had not observed this behavior when impure ferrous sulphate was used, but we did not use relatively such large quantities of impure ferrous sulphate. When the zinc sulphate was applied in small basins in which roots were exposed, little or no more was required than would be contained in the amount of impure ferrous sulphate necessary for the same degree of improvement. However, basins should be used with caution during the growing season. There was serious injury to orange trees and to one plum tree treated in the growing season from application of rather large quantities in such basins.

Trees were treated in a number of other soils, in some of which the improvement has been like that in the soils shown in Table I, but in some of which we shall have to wait until next spring for evidence. From the experience with impure ferrous sulphate, trees that have little-leaf in spring but healthy shoots with no mottling in summer are not expected to show response until the second spring after a treatment. For example, the apple trees in the sandy loam soil with a fixing power of 370 parts per million do not usually show much mottling on the shoot leaves. The little-leaf is very severe in the spring, often causing dying back, and the new shoots are from dormant buds in wood several years old. Evidence of benefit in the summer following a treatment can be seen only as increased number and length of such shoots. Since these vary greatly on untreated trees, the increase must be great to be conclusive. Impure ferrous sulphate, 100 pounds to the tree, did not cause perceptible improvement until the second spring after the treatment.

The fixing power of even sandy soils may be enough to delay improvement or to necessitate the use of unprofitable amounts of zinc sulphate. It seems probable that if there is foliage on the trees when the zinc is washed into the soil it may be drawn more quickly to the buds. The less soil a given amount of zinc sulphate covers, and the nearer the roots it is applied, the smaller will be the percentage fixed. We are, therefore, trying extensively application in the fall, while

TABLE I—RESPONSES OF TREES TO SOIL TREATMENT WITH ZINC COMPOUNDS

Character of Soil and Fixing Power (in parts per million)	Kind of Trees	Zinc Sulphate Application	Response
Sand, near neutral 175	Peach	5 lbs. Com R 7 ft. 10 lbs. Com R 7 ft. 5 lbs. C P R 7 ft. 10 lbs. C P R 7 ft.	All showed improvement by June, and all improvement about equal to that with 20–40 lbs. of impure $FeSO_4$
		50 lbs. Com R 10 ft. 100 lbs. Com R 10 ft.	Both began to show improvement early in May
Sand, near neutral 170	Peach	9 lbs. R 9 ft.	Improvement faster than with 40 lbs. $FeSO_4$
		3 lbs. R 9 ft.	Improvement considerable but less than with 40 lbs. $FeSO_4$
		6 lbs. R 9 ft.	Improvement about as with 40 lbs. $FeSO_4$
		6 lbs. R 3 ft. 6 lbs. ring 3 ft. 3 lbs. R 3 ft.	Improvement equal to that with 9 lbs. R 9 ft., or better
		1 lb. R 8 inches	Striking improvement, but less than above
		1–2 lbs. R 3 ft.	Improvement, but less than with 1 lb. R 8 in.
		3–6 lbs. mixed with ammonium sulphate	Improvement as good as when applied unmixed with ammonium sulphate, or better
		3–6 lbs. mixed with complete fertilizer: $(NH_4)_2SO_4$, K_2SO_4, and superphosphate	Improvement as goos as when applied alone
		Zinc chloride 5–20 lbs.	Improvement equal to zinc sulphate in same amounts
Sandy loam 370	Apple	15–30 lbs. R 6 ft.	Some evidence of improvement in first year
		Less than 15 lbs. R 6 ft.	No evidence of improvement in first year
Sandy loam to silt loam, Yakima, Wash.	Apple	15–30 lbs.	Apparently improved in new shoot growth
Sandy loam 390	Walnut	10–15 lbs. R 3 ft.	Very striking improvement. See Fig. 1
		15 lbs. R 9 ft.	Good improvement
		5–10 lbs. R 9 ft.	Improvement but not enough

TABLE 1—*Continued*

Character of Soil and Fixing Power (in parts per million)	Kind of Trees	Zinc Sulphate Application	Response
Sandy loam pH 8 720	Santa Rosa Plums	5½ lbs. in basins R 2½ ft. 5 lbs. + 5 lbs. $FeSO_4$ in basins R 2½ ft.	Apparently complete recovery
		9 lbs. R 7 ft. 6 lbs. R 3 ft. on surface	Apparently nearly completely recovered
		4–6 lbs. R 7 ft. on surface	Not enough
Very heavy loam with much coarse sand 810	Old Orange Trees	20–40 lbs. R 8 ft.	Striking improvement early in spring. Good summer growth free from mottling
		15 lbs. R 3½ ft.	Improvement but less than above: slow
		5–15 lbs. R 8 ft. 2–5 lbs. R 2–6 ft.	Improvement inadequate: slow
Heavy sandy loam 840	Younger Orange Trees	10–20 lbs. R 4 ft. 5 lbs. R 1 ft.	Improvement from mottling complete; growth very greatly increased
		5 lbs. R 4 ft. 2½ lbs. R 1 ft.	Improvement from mottling almost complete, growth very greatly increased
Loam with alkaline compounds 1120	Orange	20–30 lbs. R 3–8 ft. 10 lbs. R 3 ft.	Almost complete improvement from mottling; no improvement in growth
		10 lbs. R 8 ft. 5 lbs. R 3 ft.	Less improvement than above
		2½ lbs. R 1 ft. 5 lbs. R 8 ft.	Some improvement as to mottling
Loam	Orange	4–20 lbs. in basins R 2½ ft.	Striking improvement from mottling; little improvement in growth

the leaves are still drawing water rapidly through the shoots but late enough for leaf injury to do little harm to the tree, and placing the material in narrow trenches around the trunks, 1 to 3 feet away from them, the trenches being deep enough to uncover a considerable number of roots, except with citrus trees.

Corral Soils and Nitrogen Excesses

Usually little-leaf is not serious in a soil containing enough clay to be classed as a loam. However, even in such soils in areas where there have been corrals a trouble develops that resembles little-leaf,

except that it shows on trees younger than those which usually show little-leaf and may cause more severe injury to the summer shoots. The same trouble is said to develop where there have been Indian camps. Very severe corral injury to peach trees was studied in northern California in a fine-textured loam having a fixing power for zinc of about 2220 parts per million. Annual plants between

FIG. 1. Response of a Payne walnut tree to application of 15 pounds of zinc sulphate on the surface of the soil within a radius of 3 feet from the trunk. Both trees are 8 years old. Little-leaf has caused them to die back to stubs each year. The tree on the right, formerly as bad as the other, or worse, was treated January 16, 1932. Improvement was not nearly so rapid when the same amount of material was spread in a radius of 9 feet. The disease does not always cause rosettes of little leaves on the walnut. Crinkling and mottling of the leaves and dying back of the shoots are more frequent symptoms. An avocado tree as bad as the tree on the left was made to look like that on the right in the same length of time by the same treatment.

these trees made a very healthy growth. On December 8, 1932, trees were treated with 10 to 50 pounds of zinc sulphate each. When applied on the surface within a radius of 3 feet from the trunk, 10 pounds caused an improvement during the summer of 1932 but not complete recovery; 20 to 50 pounds caused an improvement that showed clearly as early as April 29 (the earliest improvement we have ever observed on deciduous trees treated through the soil) and trees so treated made a vigorous, healthy growth throughout the summer.

We have corrected this trouble also in a similar soil in an area where there had been hotbeds before the peach trees were planted. Even orange trees outside the hotbed area did not bear mottled leaves.

Because of the high fixing power, as much as 20 pounds of zinc sulphate were required to correct a tree completely. The same trouble has been studied in soils heavily manured for truck crops. If the trees are put in after some years of heavy manuring they may show the trouble in the first or second year and, after 5 or 6 years, if they live, may not be more than a few feet high, though such plants as tomatoes may make exceptional growth between the trees. Very heavy fertilizing with mineral nitrogenous compounds at least hastens the inception and accentuates little-leaf in some areas.

Since it is now certain that the corral soil injury is at least in part little-leaf, probably altogether so, and that high soil nitrogen accentuates or causes little-leaf, it seems probable that a study of corral soils and of soil nitrogen transformations might help toward an explanation of little-leaf.

Zinc Sulphate Treatment Through Holes in the Trunk

Trees were treated by placing zinc sulphate crystals in holes in tree trunks. The plan described by J. P. Bennett (2) was followed. A hole was made in the trunk about 3/8 inch in diameter and 1½ to 2 inches deep every 3 to 4 inches around it near the surface of the soil. Each hole was filled nearly full of zinc sulphate and plugged with "Tree Seal." Perhaps fewer holes and less zinc sulphate would have sufficed. Six peach trees were treated in January, 1932. In the spring they were the first trees in that soil to show benefit from zinc sulphate, and throughout the summer they made strong growth free from leaf mottling. At Sebastopol, Mr. Enoch Torpen treated two large apple trees; one was showing little-leaf rather badly and the other about as badly as it could and live. Both showed early and continouous recovery, much more striking than that shown by trees treated through the soil. In the Yakima Valley, Washington, Mr. L. L. Claypool treated five apple trees 10 to 20 years old, with about 10 to 14 grams each. These began to show benefit early in June, and by June 27 some of them had almost completely recovered. Six orange trees were treated by J. C. Johnston and J. P. Bennett. All made great improvement during the summer of 1932 as compared with untreated trees; but the response did not show sooner than in trees treated through the soil. In treatment by this method large areas of sapwood are killed. The peach and apple trees in California showed also injury to the bark above and below the holes, though the orange trees did not. With stone-fruit trees, if not also with apple trees, such injury should cause increased damage from "heart rot." The method, however, is very convenient for experimentation and many substances too expensive for soil treatments are being tried by it.

Spraying with Zinc Sulphate

During the summer of 1932, peach, apricot, and walnut trees, and grape vines, were sprayed with about 6 pounds of zinc sulphate and 6 pounds of hydrated lime in 50 gallons of water, and Mr. J. C. Johnston and Mr. N. D. Hudson sprayed orange trees with zinc-lime or zinc and a spreader. The grape vines showed striking response. Within 3 weeks after being sprayed on June 17, all vines had made good growth of shoots bearing healthy leaves, and all the leaves formed later were healthy. Untreated vines adjacent to these, and no worse before June 17, made very little growth after that date and had no healthy leaves. The results with the walnut trees seemed promising but not conclusive. Results with the other trees were inconclusive. With peaches, apricots, walnuts, and grapes, mature leaves that are mottled when sprayed continue mottled. If there is improvement it is in leaves formed after the spraying. Mottled orange leaves seem to become green under the zinc spray.

Soil Treatments with Organic Substances

In a search for evidence concerning the cause of little-leaf, a number of organic substances, namely, 10 pounds to the tree of toluene in 5 per cent solution, 5 pounds of pyrogallic acid, 5 to 20 pounds to the tree of formaldehyde in 5 per cent solution, and 500 pounds to the tree of wheat straw spaded into the soil, were applied to trees growing in the second soil of Table I. All of these except toluene certainly failed to cause any improvement during the summer of 1932, in the way that zinc sulphate did. Toluene also probably failed, but treated and untreated trees in that section of the orchard showed some improvement in 1932. The toluene treatment was therefore repeated in the fall of 1932 on worse trees. Of course, it is possible that these treatments will bring about changes in the soil that will cause improvement to the trees later.

Cause of Little-Leaf

The results reported in this paper may be held to suggest that little-leaf is caused by a deficiency of zinc for normal metabolism. Some observations, however, lead us to doubt this conclusion, namely, several of the soils here discussed are exceptionally good for every kind of annual plant that has been tried on them. Furthermore, a soil in which young trees show little-leaf in the first or second year was brought to Berkeley and placed in iron tanks painted thoroughly inside with asphalt and trees were grown in it long enough for deficiencies, of such elements as potassium and phosphorus at least, to show much more strikingly, owing to the small soil mass relative to the top, than is ever shown by trees in this soil in the orchard, and symptoms of little-leaf did not show nearly so soon, if at all. Again, in some sections, especially in the Sebastopol district, the trees in an orchard may seem about to die from little-leaf in one year and then be almost

completely healthy for a number of succeeding years, a behavior hardly to be expected from a soil deficiency. Dr. H. L. Crane says in a letter written October 22, 1932, that work by investigators of the U. S. Pecan Field Laboratories, Albany, Georgia, indicates that pecan rosette may be partially or completely cured by treatment with zinc sulphate through the soil, through holes in the trunk, or by spraying. Alben *et al* (1) found similar results in Louisiana. Thus it appears that little-leaf may injure trees in all of the lighter soils, with their diverse geological origins and conditions of weathering, from the Canadian boundary in Washington southward to Mexico and eastward to Georgia, and even in most of the heavier clay soils if treated with much manure or with much of some other nitrogenous compounds, though it has not been reported to injure trees growing in any of the soils of even more diverse geological origin north of Arkansas and east of the Rocky Mountains, or even in sections near the little-leaf area if the summers are relatively short or cool. It does not seem probable that an element would be so universally deficient over such an extensive and diverse area and never deficient in contiguous areas as extensive and as diverse. It seems more probable that some climatic influence may be responsible for the distribution of little-leaf.

A. Koslowski, in co-operation with D. R. Hoagland, has been studying the soil flora in relation to little-leaf. Chromogenic bacteria, producing very toxic substances, have been isolated from soils in sections where trees show little-leaf. On young seedling peach trees in water and sand cultures these bacteria have caused a growth that somewhat resembles little-leaf, though the observations are not conclusive. The bacteria that produce the most toxic substances require for their best growth a rather high soil temperature. Careful observations in fruit growing district close to the ocean where the summer temperatures are very low disclose no little-leaf even on trees growing in very sandy or gravelly soils. In the Sebastopol district where the temperature does not usually remain high very long, little-leaf was worse in the spring of 1932, following the exceptionally hot summer of 1931, than it had been for at least 9 years.

There is a preliminary suggestion that the toxic substances from these organisms are precipitated by compounds of zinc, mercury, and silver; also by compounds of calcium, in higher concentration. Compounds of these elements are being used to treat little-leaf trees through holes in the trunks to see whether substances other than zinc will cure little-leaf and whether the elements that cure little-leaf are the same as those that precipitate the substances to which, pending the completion of research now in progress, the toxicity is attributed. We are aware that these observations are only suggestive, but they lead us to think that a study of the soil flora may be a more promising direction for research concerning the cause of little-leaf than a study of zinc deficiencies in the soil.

In addition to the farm advisers listed last year, we have had generous assistance from H. L. Washburn, A. A. Tavernetti, E. F.

Smyth, H. J. Wilder, R. V. Wright, R. D. Foot, C. S. Myszka, and B. L. Smith. L. L. Claypool did the work with apples in Washington; J. C. Johnston and N. D. Hudson that with oranges in California.

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Pecan Rosette, a Physiological Disease Apparently Susceptible to Treatment With Zinc[1]

By ALTON H. FINCH, *University of Arizona, Tucson, Ariz.*

ROSETTE is a physiological disease of pecan trees known wherever they are grown in the United States. It was one of the first serious diseases to develop with the commercial planting of pecans, being recognized by growers in the Southeast as early as 1900. Its occurrence in Arizona was recorded in 1911.

In general, the first symptoms of the disease are a slight and frequently mottled chlorosis of the newer tipmost leaves, often evident as the leaves unfold. Affected leaves continue chlorotic and remain small. Leaflets develop prominent veins, become crinkled, brittle and are malformed. In advanced stages a necrosis of the shoot is initiated near the tip and progresses toward the base. Trees badly affected are not productive. Trees affected while young become misshapen, make unsatisfactory growth, and are generally rendered worthless.

Investigations of pecan rosette initiated in the fall of 1931 and continued through 1932 have indicated that this disease as it occurs in the Southwest is not related to soluble salt content of the soil or to soil pH.

Studies of the effects of various chemicals upon trees affected with rosette were begun in April 1932 and continued throughout the summer. The materials used were, c.p. ferric chloride, U. S. P. ferric citrate and ferric ammonium citrate, and commercial iron sulphate; c. p. magnesium acetate and magnesium citrate; c. p. manganese acetate and manganese citrate; c. p. zinc chloride and U. S. P. zinc sulphate; c. p. mono-potassium phosphate, c. p. ferric phosphate and commercial treble superphosphate; c. p. acetic acid; c. p. sulphuric acid; and tannic acid of unknown purity.

Each of these materials was applied in one or more of the following ways: (1) by placing the dry chemical in holes bored into the tree trunk, (2) by dipping or spraying leaves and leaflets with solutions of various concentrations, and (3) by injecting similar solutions into the trunks of affected trees.

The studies were chiefly on trees in the third, fifth, and eighth growing seasons, located in the South Gila Valley where rosette has been particularly serious. From April to August 4, only the trees in the fifth growing season were treated. These had been severely cut back and heavily mulched during the previous winter. The new diseased growth of many untreated trees evidenced recovery during early summer before the disease was far advanced. This fact tended to mask any results that might have been produced by the treatments up to that time. By late June, many un-

[1]A more complete report on the progress of this project will appear as a bulletin of the Arizona Agricultural Experiment Station.

treated trees had become severely affected, to the extent of "burning" and loss of leaves. Thereafter, treatments were confined to such trees. In no case did those selected as checks show any improvement.

Striking and consistent results have been obtained from the use of the two zinc salts. Of 52 trees treated during the summer by placing zinc sulphate or chloride in holes bored into the trunks, all have produced healthy growth following the treatment and have remained healthy throughout the season. Four trees injected with 1 pint of a 1 per cent zinc chloride solution likewise became healthy.

As the disease advances, leaves on the topmost shoots turn brown. "burn," and drop off. The shoot itself begins to turn brown, the terminal bud and upper lateral buds often die, while the lower lateral buds break into weak growth. The response to zinc treatments made at this stage was particularly striking. Shoot necrosis was arrested. In 3 to 6 days following the introduction of the zinc salt, the new leaves unfolding from the lateral buds became definitely greener. In 15 to 20 days after treatment the leaves were completely unfolded and several inches of healthy shoot growth had been made.

Young leaves or leaflets showing definite chlorosis or other symptoms of the disease became much greener and displayed general improvement in 3 to 6 days after dipping in a .01 per cent to .1 per cent solution of zinc chloride or .1 per cent to .5 per cent zinc sulphate solution. Spraying with the same solutions produced similar effects. Improvement resulted only in the parts wetted by the solutions. Where only a portion of a single leaflet was dipped, that portion alone improved.

The commercial iron sulphate gave somewhat comparable though less uniform and less pronounced results. Analysis of this material revealed an appreciable zinc content. Chemically pure and U. S. P. iron salts, as well as other materials used, were without effect. There seems little doubt but that the responses observed are related to the action of zinc, although this point is not yet considered established. Assuming that the results described are due to zinc, the method of its action is not yet clear.

Some evidence would seem to point to a simple zinc deficiency. Only young tissues still in process of growth were improved. The treatments may have supplied the zinc necessary for proper development of the tissue, where possibly a deficiency existed previously. Very dilute solutions of zinc produced a less definite improvement of affected leaves than did stronger solutions up to the point of burning—suggesting a quantitative relationship.

Analyses of leaves, stems, and shoots have tended to support this view. These materials were collected from (1) healthy trees in the Yuma Valley where rosette has not been serious, (2) healthy trees in the South Gila Valley where rosette is serious, (3) a tree in the South Gila Valley, healthy at the time of collecting samples but seriously affected prior to applying 6 grams of zinc

chloride in the trunk (samples collected 55 days after treatment), and (4) a severely rosetted tree in the South Gila Valley which was a check for the tree supplying the samples of number 3. These analyses showed that the zinc content was greatest in (1) and diminished successively to (4).

The acids used whether applied to the leaves or introduced into the trunks of diseased trees did not produce improvement either directly or through making available any materials already present. Studies made microscopically on free hand sections have not shown consistent differences in pH between healthy and diseased tissues.

The only districts in Arizona known to be essentially free of rosette are the Yuma Valley or other sections irrigated with waters of the Colorado River. This water was analyzed and found to contain a small amount of zinc. In five locations where rosette is common, the irrigated water contained no zinc.

One severely rosetted 7-year-old tree was excavated for examination of the roots. No abnormality that could be associated with the diseased condition of the tops was found. If, from this limited study, the true condition has been indicated, the problem of overcoming rosette is simplified to one of correcting the condition in the above-ground parts. Perhaps the roots are better able to obtain zinc or depend less upon it for their proper functioning than do the stems and leaves. Root growth in relation to rosette is being investigated further by Mr. Tatum.

No applications of zinc or other materials to the soil were made during the course of these studies. It was believed that because chemicals in the soil are not necessarily available to the plant, more indicative results would be obtained by applying materials directly to the tree. Similarly, no analyses of soils for zinc have been made. Studies of the zinc-fixing power of various soils in Arizona, and experiments on the control of the disease through the addition of zinc salts to the soil and to the irrigation water are now being initiated.

Some Effects of Deficiencies of Phosphate and Potassium on the Growth and Composition of Fruit Trees, Under Controlled Conditions

By D. R. Hoagland and W. H. Chandler,[1] *University of California, Berkeley, Calif.*

FOR a number of years, the Divisions of Pomology and Plant Nutrition have been carrying on investigations of certain diseases of deciduous fruit trees involving questions of soil and plant interrelations. In connection with these general investigations, experiments are being made in Berkeley with prune, peach, and other fruit trees under controlled conditions, several hundred young trees having been under observation. For this purpose, closed steel cylinders of 1000–1200 pounds capacity, sunk in the ground and provided with drainage tubes, are employed, as well as above-ground containers of approximately 300 pounds capacity. Treatments were replicated three to five times. Notwithstanding some inevitable tree variability, no inconsistency has appeared leading to doubt concerning the main conclusions. The effects to be discussed are of large magnitude. Details of methods cannot be described in this paper because of space limitations.

Effects of Potassium Deficiency in Prune Trees

In certain areas of the Sacramento Valley, prune trees (especially the French prune) have become severely injured by a disease known as "dieback." A description of this disease under field conditions is being reported by Lilleland. The present statement is confined to controlled experiments of the type mentioned above. Soils of different characteristics were used for study, several of them being from orchards showing marked "dieback" injury. One soil, obtained in Berkeley, was considered to possess a high degree of fertility.

Among the soils from dieback areas, one produced marked stunting of growth, as well as some leaf scorch, the first year the trees were planted. In another soil, no certain injury appeared until the fourth year, but from the fourth to the sixth year trees have been increasingly affected, showing definite leaf scorch as early as June. Two other soils included in the experiment have given no evidence of potassium deficiency, with the exception of one tree during one season. At this time the tree bore an exceptionally heavy crop for the conditions involved. In addition to yellowing and leaf scorch, there appeared during two seasons another general type of leaf symptom, characterized by small irregularly scattered purple spots early in the spring followed by the dying and excision of affected areas of tissue, finally giving the leaf a perforated appearance (Fig. 1). This type

[1]Acknowledgment is made of the indispensable aid of A. H. Furnstal, in charge of technical service.

of injury first appeared on the sunny side of the tree in every case. No evidence of an organism could be obtained. During the past season this second type of leaf symptom has been almost absent, and the first type (yellowing and scorch) is the one characteristic of field conditions, although the other symptoms may sometimes be found.

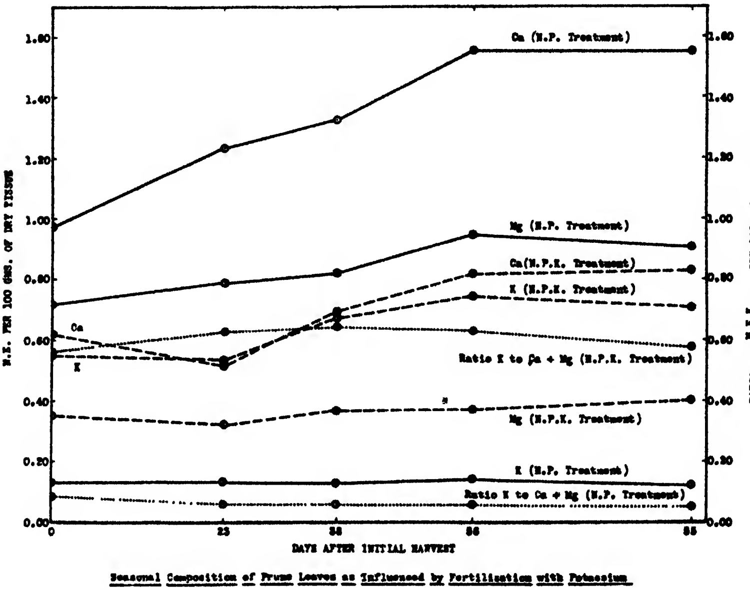

FIG. 1. Composition of leaves of prune trees grown in soil producing dieback as affected by potassium fertilization. These trees were grown in cylindrical tanks of approximately 1000 pounds capacity. Collection of leaves was begun May 25.

The heavy application of potassium salts (in such manner as to influence the whole mass of soil) at the time of planting the trees completely prevented the appearance of leaf scorch symptoms and at least 90 per cent of the other symptoms. Even after trees had become severely injured, application of potassium salts during the winter brought about striking improvement the following summer in every instance, and certain trees resumed normal growth. The difficulty of producing similar effects under field conditions is pointed out by Lilleland. The following factors seem to be involved: (a) Exceptionally heavy bearing characteristic of the prune area involved. In the controlled experiments the trees were young and crops relatively light. (b) High fixing power of soils for potassium preventing distribution of added potassium throughout root zone when ordinary amounts of potassium salts are applied to the soil. (c) Very hot, dry climate in comparison with cool, moist climate of Berkeley. Under the latter conditions, no trees have died, even though severely injured. Under field conditions, death of trees is common.

In this investigation, many studies have been made on the composition of leaves and of other parts of the tree as influenced by soil treatment. The inorganic composition of the leaf throughout the season (including young leaves not yet showing injury) reflects con-

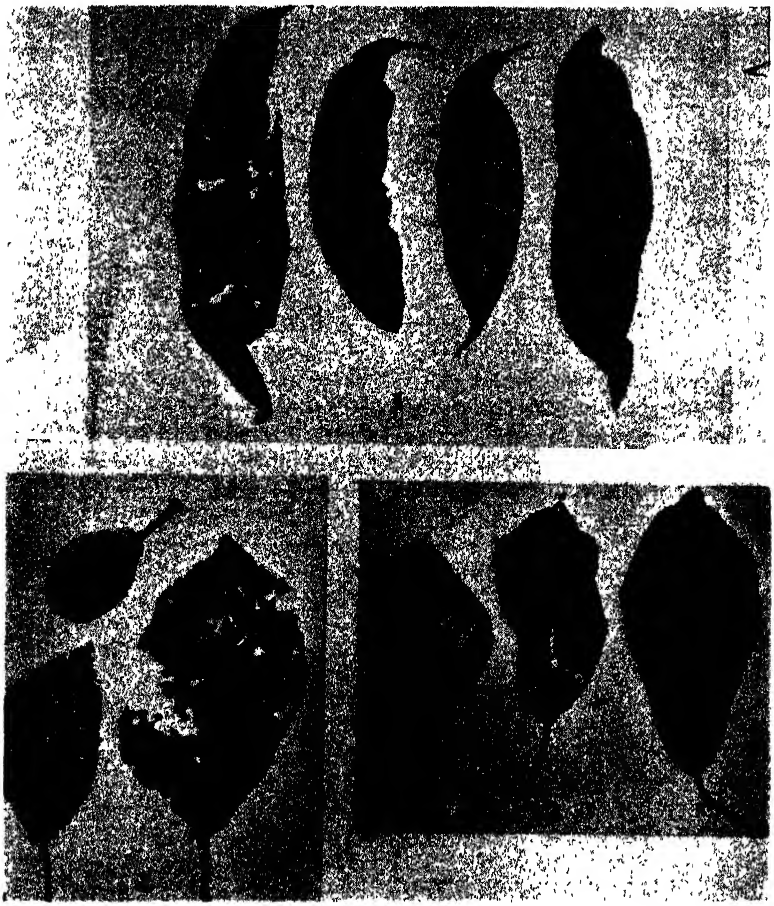

FIG. 2. 1. Leaves from trees grown in sandy soil with different culture solutions as follows: beginning at left, (a) complete minus K; (b) complete minus P; (c) complete minus N; (d) complete. 2 and 3. Leaf symptoms of dieback disease of prune trees, associated with potassium deficiency. 3 shows symptoms mainly characteristic of field conditions.

sistently the availability of potassium in the soil. It should be noted, however, that difficulties in interpreting leaf analyses may arise when older trees bearing heavy crops are studied. Interrelations between the absorption of potassium, calcium, and magnesium are very significant. Increased absorption of potassium consequent on fertilization

of the soil with this element is accompanied by decreased absorption of calcium or magnesium, or both, the increase in the ratio of potassium to calcium plus magnesium present in the leaf $\left(\frac{\text{milliequivalent K}}{\text{(milliequivalent Ca and Mg}}\right.$ per 100 grams dry tissue) being very large. Only one example of this interrelation (Fig. 2) is now presented, but data available for all the soils used all lead to the same general conclusion.

In other experiments, it was shown that when magnesium carbonate(1 per cent) was mixed with a soil low in available potassium, greatly increased tree injury occurred. To a lesser degree the same effect was caused by calcium carbonate (3 per cent). The injurious effect of magnesium carbonate could be largely overcome by the addition of potassium to the soil and that of calcium carbonate entirely so. The effect of potassium seemed to lie primarily in its influence on the relation between calcium, magnesium, and potassium, not on the soil reaction. The soil already described as producing greatest injury to prune trees contained about 1 per cent carbonate, possibly including some magnesium carbonate, as well as an unusually high proportion of replaceable magnesium. Wallace (1) has emphasized the possibilility that when magnesium is relatively low in a nutrient medium, high potassium may induce a magnesium deficiency. It is the reverse case that we have just considered. It may be added at this point that some interesting data are available on the sap buffer systems of prune leaves as influenced by potassium, calcium, magnesium relations. There seems to be a tendency for low potassium content of the leaf sap to be accompanied by increased hydrogen ion concentration.

Effect of Potassium and Phosphate Deficiencies on Peach Trees

The trees (Tuscan variety) have been grown since 1928 in Delhi sandy soil under cultural conditions similar to those already described. The following treatments of the soil were made at suitably repeated intervals, namely, (a) complete culture solution, including "X"[2] solution, (b) complete culture solution minus K, (c) complete culture solution minus P, (d) complete culture solution minus "X" solution. After the trees were 2 or 3 years old, the amount of soil available relative to the size of the tree was, of course, much smaller than under field conditions. Thus deficiencies of potassium and phosphate became evident under the experimental conditions, although not thus far observed in the field for the same soil.

Symptoms of potassium and phosphate deficiency were very similar in general type to those reported by Wallace (2) for various horticultural plants (see Fig. 2). The phosphate-deficient peach trees were characterized by restricted growth and by purplish tints in the leaves. During the past season, many leaves near the ends of the

[2]Solution containing very small amounts of Al, I, Br, Ti, Sn, Li, Mn, B, Zn, Cu, Ni, Co.

twigs assumed a deep purplish bronze color, distinguishable from the lighter and more reddish tints caused by marked nitrogen deficiency. Leaf size was diminished. The potassium-deficient trees made more growth during the past season than the trees receiving the complete solution, but the leaves were light in color and mottled, showing distinct vein patterns. Late in the summer, they showed dead tips, rolling, and scattered perforations. Trees not receiving the "X" solution have become significantly less thrifty and certain abnormal leaf symptoms have appeared, different from those produced by nitrogen, phosphate, or potassium deficiency. Conceivably these may be related to "little leaf" disease occurring in this soil under field conditions, discussed in another report.

Effects of Phosphate and Potassium Deficiencies on Character of Fruit

Since no doubt existed that these trees were being influenced by known deficiencies, a condition not often available for study in the field, the character of the fruit is of considerable interest. For three successive seasons, the phosphate-deficient trees produced fruit with dark spots, subject to quick decay. In 1932, systematic observations were made on fruit gathered from July 23 to August 16. The set was heavy on all trees except those lacking potassium and the fruit was thinned early in the season. Evidence of tissue breakdown in fruit from the phosphate-deficient trees was consistent. Furthermore, such fruit ripened earlier, not later, than fruit on trees with the other treatments. It is a common view based largely on observations on grain plants, that phosphate promotes early ripening. The comparison between plants with such different types of reproduction is evidently not valid.

In 1932, the potassium-deficient trees produced a much lower yield of fruit than the other trees. The fruit was characterized by delayed ripening and by marked lack of color, extending to the flesh surrounding the pit. The omission of the "X" solution did not noticeably influence fruit quality, though it affected adversely the general condition of the tree, as already stated.

It should be noted that we have not established the existence of phosphate or potassium deficiencies in this soil under field conditions, and also that we have not observed significant effects of potassium or phosphate deficiencies on quality of fruit except when the deficiency was sufficiently accentuated to be reflected in foliage symptoms.

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Experiments in K and P Deficiencies With Fruit Trees in the Field

By OMUND LILLELAND, *University of California, Davis, Calif.*

PART I—POTASH

IN 1921 the attention of the California Agricultural Experiment Station was called to a development of scorch of the foliage of Agen prune trees in the upper Sacramento Valley. The area affected became larger as new orchards came into bearing, and now the trouble seriously threatens some 15,000 acres of trees located in Butte, Tehema, and Glenn Counties. Detailed studies in the field and in the laboratories of the plant nutrition and pomology divisions have been carried on since 1926 and it is fairly well established that faulty potassium nutrition of these prune trees is an important factor in the development of the trouble.

Symptoms. Prune trees in the affected districts generally make excellent growth during the first 5 to 8 years in the orchard, often excelling those of similar age in the prune sections free from this trouble. Scorching of the leaves is in most instances associated with heavy cropping and the first injury may come with the first heavy crop. In the better soils it may not appear until four or five crops have been harvested and in the worst soils symptoms may be recognized before any crop has set. A slight chlorosis sometimes precedes the actual scorching, though this is not general. The trouble is a collapse of well-grown trees in contrast to the stunted growth reported in other potassium deficiency studies. Trees which appear quite normal in early summer may show serious scorching in a period as short as 1 week and die the same season. Sometimes the scorch causes premature defoliation in which case the tree sends out a new crop of weak leaves which in turn scorch and fall, and eventually the tree dies.

The scorching and subsequent dying is first evidenced in the top of the entire tree. The lower leaves and spurs in the crotch are the last to succumb. Though instances of the death of some trees have been recorded during the first season of scorching, many trees suffer only a dying back into 2- and 3-year-old wood and continue to live for several seasons. Repeated scorching generally reduces the bearing area, however, so as to make the trees unprofitable and sooner or later they are removed. Growers refer to the trouble as prune die-back.

There appears to be no definite leaf pattern as far as the scorch is concerned. Tip, marginal, and central burning are all in evidence. The Agen is the most extensively planted variety, and although direct comparisons are not always possible, it is probably the most seriously affected. The other commercial varieties, Robe de Sergeant, Imperial, and Sugar, are, however, not entirely non-susceptible. The Italian appears to be entirely unaffected. Other species of fruit trees are not affected. Healthy peach and almond trees may be observed

interplanted with prune trees seriously injured by die-back. Scattered pear and apple trees exhibit no symptoms. Potash fertilization is not carried on commercially with crops in this area.

Rootstocks. Though peaches, almonds, and myrobalan plums show no injury, the Agen prune, when top-worked or budded on these species, develops die-back symptoms. There is a little evidence that the injury is not as severe on the myrobalan as on the peach root.

FIG. 1. The prune trees on the left received 10 pounds of K_2SO_4 per tree injected with 75 gallons of H_2O into the soil in January 1927, before any injury had developed. The row on the right was untreated. The picture taken in June, 1929, shows that the addition of potassium has delayed the development of serious die-back symptoms. However, both treated and untreated trees succumbed later. The excellent growth made by these 10-year-old prune trees in this low K soil should be noted.

Causal factors. Many organic and inorganic fertilizer materials and chemicals have been tried in the field, including barnyard manure, dried blood, $Ca(NO_3)_2$, $NaNO_3$, $(NH_4)_2SO_4$, treble superphosphate, $Ca(Cl)_2$, $MnSO_4$, $MgSO_4$, $FeSO_4$, $CaSO_4$, $CuSO_4$, H_2SO_4, S, K_2SO_4, KCl, potassium alum, and a salt mixture containing Co, Br, I, Cr, Sr, Ba, Sn, Zn, Ni, B. Pb. Large quantities have been used and where possible the application has been injected into the soil to insure proper distribution (1). Response has been obtained only when the fertilizer salt applied contained potash.

Response to Potash. In no case has it been possible to cause improvement in trees already afflicted with die-back symptoms. Applications of 10–15 pounds of either the muriate or sulfate of potash or 40 pounds of potassium alum per tree in a 7-year-old orchard have

delayed the development of the scorch in healthy trees for one or two seasons but eventually these treated trees have shown serious scorching even when the treatments have been repeated annually (Fig. 1). No explanation can be given for this behavior and trials are now established where potash is being applied annually from the time of planting. The tank experiments reported by Hoagland in which the symptoms can be produced in soils transported from these areas to Berkeley and there corrected by K fertilization and other confirmatory field data strengthen the credibleness of the diagnosis as a potassium deficiency.

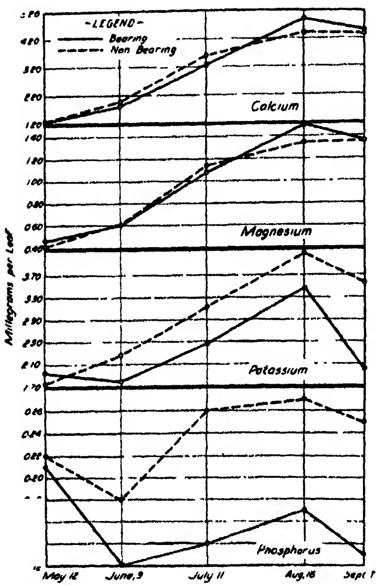

FIG. 2. Seasonal changes in the ash constituents in the leaf of adjacent prune trees as influenced by the early removal of crop from one of the paired trees.

Climate, Tree Growth, and Soils. The area in which die-back appears, is in the northern part of the Sacramento Valley and has a dry, hot summer with an average seasonal rainfall of 25 inches falling between October and May. The high summer temperatures may intensify the severity of the injury, though other interior valley prune districts (Colusa and Anderson) which differ little climatically from the die-back areas, are comparatively free. The coastal valley prune areas (Santa Clara and Sonoma) which are free from the trouble are characterized by a milder climate. Many of the orchards in the die-back areas are irrigated, and young prune orchards appear exceedingly thrifty and have a pronounced tendency to set very heavy crops. The soils are deep, loamy, alluvial deposits of good tilth and are well drained. Analyses of some 200 soil samples from healthy and diseased orchards, too extensive for discussion here, indicate a dearth of potash in the severely affected orchards.

Effect of Cropping. Removal of the entire fruit crop by hand early in the season has prevented the development of the trouble, while contiguous trees have shown severe die-back symptoms. The marked influence of fruiting on the potassium content in the leaf is shown in Fig. 2. The paired data are from adjacent trees which have received identical treatment except for cropping. Analyses of approximately 500 leaf samples show that leaf analyses of bearing trees do not reflect the level of potassium nutrition within the tree accurately enough to make predictions as to whether or not die-back symptoms will

develop. Large differences, ascribable to variations in yields, have been noted when the leaves of a particular tree have been studied over a number of seasons. Furthermore, healthy trees bearing light crops, though they subsequently scorch when bearing heavily, may show as high potassium content in the leaf as heavily loaded trees in a nonscorching, high-potassium district. Reducing the crop through pruning has prevented the development of scorch in one of the experimental plots during the past season. The healthy appearance of barren trees which, for reasons unknown, bloom profusely but fail to set also stresses the importance of bearing on the development of the die-back symptoms and the potash deficiency within the tree. The appearance of the scorch is sudden—an orchard which appears normal may develop severe damage in a week. Analyses of the developing prune fruits indicate that at the time of appearance of the injury the withdrawal of potash by the fruit is greatest.

Part II—Phosphorus

A residual soil in the Pacific ridge section east of Chico, known as the Aiken series, is exceedingly low in phosphate and marked responses have been obtained from this element with potatoes, vetch, and strawberries. In a 10-year-old J. H. Hale peach orchard and in a 15-year-old Rome Beauty apple orchard, 50 pounds of treble superphosphate per tree have been added annually since 1929. The material has been applied with the soil injection apparatus, and absorption of the phosphate by the trees has been confirmed annually by leaf analyses.

The peach trees have shown a singular behavior. The fertilized trees appear thriftier than the checks early in the season, with larger and darker foliage. In August the foliage of the treated trees seems yellowish green in comparison to the check trees. The treated trees retain their leaves longer and do not develop purple tinted foliage late in the season as do the untreated trees.

The yellowing of the foliage caused by the application of phosphate has been noted in another orchard and is in agreement with the observations made by De Werth and Chadwick (2). The treatments have not been continued long enough to show whether application of phosphate to the peach trees in the low phosphate soil is detrimental. Frost and hail injury have prevented obtaining accurate yield data on these plots. The time of bloom, time of ripening of the fruit, and the amount of shoot growth have not been affected.

The cause of the yellowing of the foliage is presumably a depression of nitrogen absorption caused by the addition of phosphate. Leaf analyses consistently show a lower N content in the treated trees. Addition of $Ca(NO_3)_2$ with the treble phosphate prevents the yellowing. The check trees do not exhibit any marked signs of N deficiency. The phosphate-treated trees show, in addition to the lower N content, higher amounts of K, Ca, and Mg. There appears to be a definite migration of P from the leaf into the wood prior to leaf fall.

No differences have been observed with the apple trees, though leaf analyses indicate a higher P content in the treated plots.

Discussion

The observations made by Wallace (3) both with regard to potash and phosphate are in agreement with the field data thus far obtained. Concerning potash deficiency, he says, "It is usually very difficult to remedy by ordinary manurial means in the case of fruit trees when the deficiency effects are strongly developed," and on phosphorus he comments,....."no case of proved phosphorus deficiency has been observed in our work in the field, not even in cases when soil phosphorus has been insufficient to grow pasture plants healthily. It then appears that the fruit plants with which we are concerned are good phosphorus feeders."

It may be necessary in cases of potassium deficiency to fertilize the tree from the time of planting to secure complete correction. Such tests are now in progress. It is quite evident that all species of fruit trees do not have similar potash requirements.

The failure of deciduous fruit trees to respond to phosphorus in a soil very deficient in this particular element and in which other crops show marked increase in growth suggests that phosphorus fertilization of orchard crops may often be of questionable value.

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The Influence of Storage Temperatures on the Dessert and Keeping Quality of Peaches

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ALTHOUGH peaches cannot be held in storage for any extended time, they are often stored for a few weeks to extend the marketing period, and they are often shipped considerable distances and exposed for varying lengths of time to different temperatures. It is important, therefore, to know the effect of different temperatures on the ripening and quality of the fruit and to determine the most desirable storage temperature and the maximum length of time that fruit may be stored advantageously. The investigation reported here was inaugurated in 1930. The work of that season was preliminary in nature; therefore this paper deals largely with results obtained in 1931 and 1932.

MATERIAL AND METHODS

The work was outlined, first, to determine the effect of high temperatures (80 to 50 degrees F) on ripening and dessert quality; second, to ascertain the cold storage temperature at which peaches can be held best and the length of time they may be held and subsequently ripened. Storage temperatures of 40, 36, 32, and 30 degrees were used, and samples of the fruit were transferred from these temperatures to 70 degrees at weekly intervals for ripening and inspection.

Carman, Belle, Elberta and J. H. Hale* peaches were obtained from an orchard near Leesburg, Virginia; they were selected for uniform maturity from commercially picked lots. The fruit was delivered by truck a few hours after picking to the Cold Storage Laboratory at Arlington Farm, Virginia, and stored immediately on arrival. At the time of storage and at frequent intervals thereafter the firmness of the fruit at the different temperatures was determined by pressure tests (1) using a plunger $\frac{5}{16}$ inch in diameter with a penetration of $\frac{5}{16}$ inch.

Chemical analyses were also made, the results of which are not included in this paper.

DISCUSSION OF RESULTS

Firmness in Storage. The firmness of the fruit at all of the storage temperatures used as shown in Fig. 1 graphically for Elberta peaches in 1932, is representative of the general trend for all varieties studied. Although there were differences in firmness between

*The fruit was obtained as J. H. Hale, but in 1931 its identity was questioned by Mr. H. P. Gould and others.

varieties at the time of picking and in the firmness of the same variety from year to year, the general trend of the curves remained unchanged. Softening at 80 and 70 degrees F was very rapid and even at 60 degrees a full soft condition was reached in about 7 days. At 50 degrees softening was considerably slower and at 40 degrees much more so. At the lower temperatures practically no softening occurred and in many instances the fruit became significantly more firm.

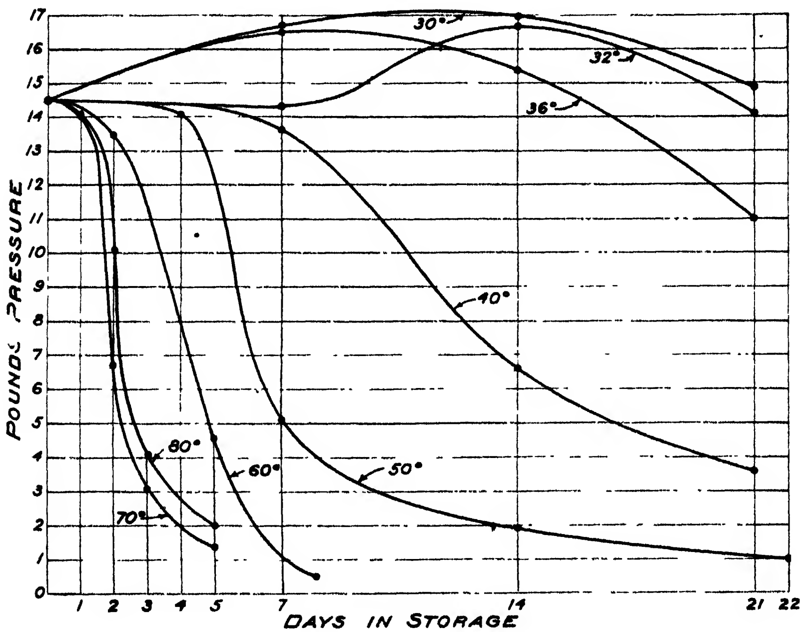

FIG. 1. Firmness of Elberta peaches in storage at various temperatures as indicated by pressure tests. 1932.

Effect of High Temperatures. Ripening processes went on at about the same rate at 70 and at 80 degrees F, and the fruit had good quality after 3 to 4 days, depending somewhat upon the variety and the degree of maturity when picked. After becoming ripe the fruit could be held 3 to 4 days longer without appreciable loss in dessert quality, but not without a considerable increase in decay. Peaches held at 60 degrees F were in eating condition after 8 to 10 days and the dessert quality was rated as fair to good. At 50 degrees the fruit was yellow and soft after 15 to 20 days. The dessert quality, however, was inferior, especially in Carman, Belle and Elberta.

Peaches designated as lacking in dessert quality showed such characteristics as pronounced acidity, bitterness or astringency, or lack of flavor and aroma.

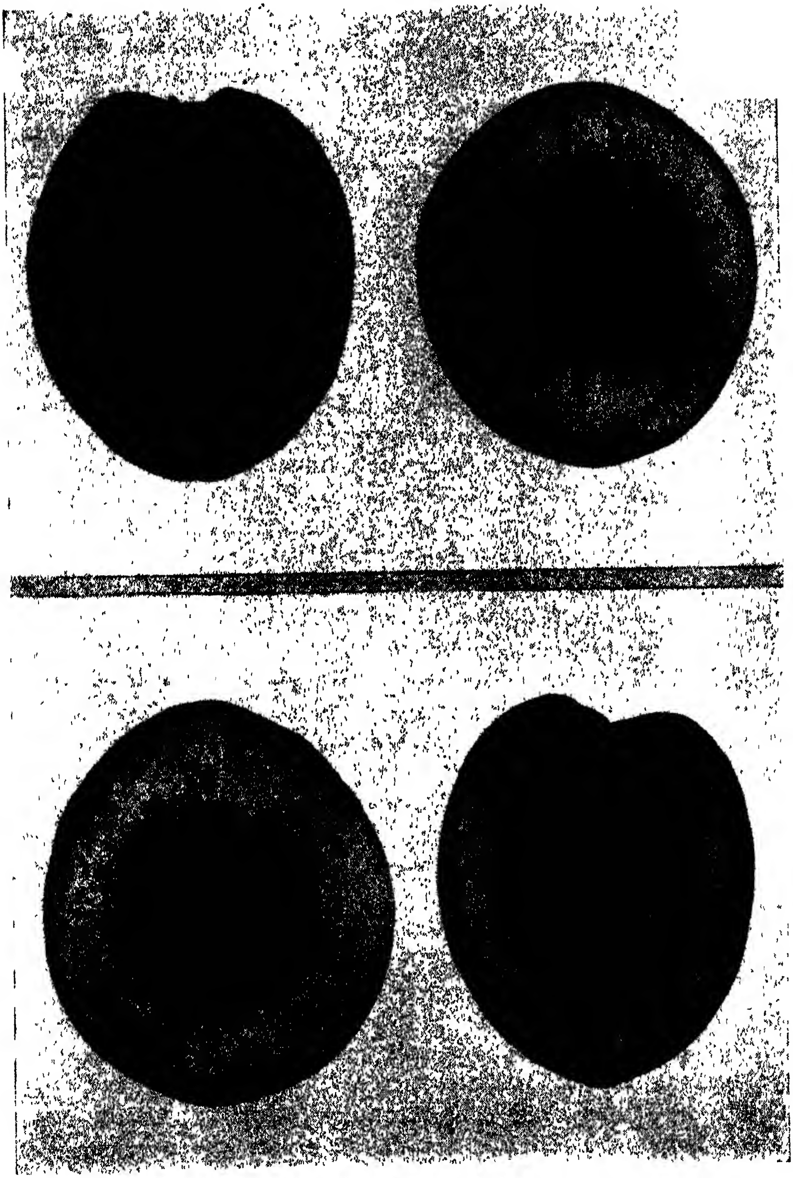

FIG. 2. Elberta peaches showing the beginning of breakdown after 3 weeks at 36 degrees and 3 days at 70 degrees F. Lower—Elberta peaches showing breakdown after 3 weeks at 40 degrees and 3 days at 70 degrees F.

Effect of Cold Storage Temperature. Storage temperatures of 36 and 40 degrees F resulted in a high percentage of breakdown, which developed either in cold storage or during the ripening at 70 degrees. High percentages of breakdown were not found in the lots transferred from the lower temperatures to 70 degrees for ripening at the end of the first week but were usually found in the lots transferred after the second week. By the third week, breakdown was in evidence at the time of transfer. In all the varieties studied, higher percentages of breakdown were found in the lots stored at 40 degrees than at any of the other temperatures. J. H. Hale and Elberta peaches were less susceptible than were Carman or Belle. Less breakdown of all varieties was noted in 1931 than in 1932. Fruit of each variety was about twice as large in 1932 as in 1931.

Cultures were made from the tissue showing breakdown. That the trouble was physiological was indicated by the failure to isolate any organisms from the affected tissues. The first indication of breakdown was a water-soaked appearance around the stone. In later stages the water-soaked areas became larger and turned brown, and eventually all of the flesh became brown and mealy. Some of these stages of breakdown are illustrated in Fig. 2.

A disease of peaches similar to that herein reported has been noted by Scurti and Pavarino (4) to which they applied, provisionally, the name "male raggiante" (ray disease). Powell and Fulton (3) likewise have pointed out a deterioration and discoloration of the flesh of peaches after storage at 36 and 40 degrees F for 10 days or 2 weeks. On the other hand, Morris (2) reports that "Storage temperatures varying from 40 to 45 degrees kept the fruit in good condition, retarded the softening processes, but permitted normal ripening of mature fruit so that good quality material was drawn from the storage rooms from 5 to 15 days after harvest."

In the present investigation it was found that when Carman, Belle, Elberta, and J. H. Hale peaches were stored at 32 degrees F for 1 or 2 weeks and then transferred to 70 degrees for ripening, they developed good dessert quality. However, when storage at 32 degrees was extended to 3 weeks before transfer to 70 degrees for ripening, Carman peaches rated only fair in quality and were slightly acid; Belle were poor, mealy and off flavor; Elberta were fair to poor and decidedly lacking in aroma and were slightly astringent; Hale were rated fair, slightly acid, astringent, and mealy.

In most instances all four varieties of peaches were held in storage longer than 3 weeks, but when this fruit was ripened at 70 degrees F it was found that the additional storage had sacrificed dessert quality. Such fruit was often classified as in fair condition and edible, but still was of poor quality for the variety.

With longer storage at 32 degrees, breakdown developed during ripening at 70 degrees.

Storage at 30 degrees F was unsatisfactory because of the narrow margin between the maximum freezing point (average 29.74) of peaches (5) and the storage temperature. In 1931 freezing injury was noted in Carman, Belle, and Elberta, and in 1932, in Elberta. When freezing did not occur, the peaches stored at 30 degrees in some instances ripened at 70 degrees with distinctly better quality than comparable fruit from 32 degrees. This points to a possible optimum cold storage temperature of 31 to 32 degrees, but if such a range is used the temperature must be controlled accurately to guard against freezing.

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Varietal Behavior of Strawberries and Peaches Preserved by Frozen Pack Methods

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STUDIES of frozen pack preservation of fruits and vegetables have thus far been primarily concerned with the development of the technique of preparation and treatment of the material or of applying cold, and have given only scanty and rather incidental attention to varietal behavior. Limitations of space preclude any review of the results of Turnbow and Cruess, Culpepper, Caldwell and Wright, Diehl, Fabricius, Mack and Fellers, Woodroof, and Tressler, who have reported upon varietal responses to freezing treatments.

The rapid development of freezing preservation in ready-to-serve consumer packages brings the products into direct competition with the same fruits in canned or in fresh form. Since the canning industry has been at work for many years upon the development of standards and the improvement of uniformly graded products of the highest possible quality, it is apparent that the frozen pack method of preservation can establish itself against such competition only by confining itself to packing such material as it can deliver to the consumer with a close approximation to the appearance and dessert quality of the fresh fruit.

It is inherently probable that varietal factors will be highly important in guiding this selection of material and that the physical and chemical differences between varieties will result in as great diversity in appearance, texture, palatability, and general desirability of the products made by freezing as is observed when assemblages of varieties are preserved by canning.

The studies of varietal adaptability to freezing purposes here reported were begun in 1930. To date, 18 varieties of peaches and 64 varieties and unnamed selections of strawberries have been studied. The peach material was grown at Arlington Farm, Virginia, or in nearby orchards and the strawberries at Norfolk, Virginia, Salisbury, Maryland, or at Glenn Dale, Maryland.

All comparisons here made are based on results obtained with peaches packed in 50 per cent sugar sirup, and strawberries in 70 per cent sirup. Hermetically sealed No. 2 plain tin cans and a liquid-tight but not air-tight paper cup of approximately equal capacity were used with both fruits. Ordinary slow freezing in a 16 degrees F room, used as a routine procedure with all varieties of peaches and strawberries, was compared with very rapid freezing accomplished by surrounding the containers with crushed solid carbon dioxide, which was used with Aroma strawberries and seven varieties of peaches. All material was stored at 17 to 18 degrees F for approximately 6 months before examination.

The material afforded opportunities for study of the effects of slow and very rapid freezing, with and without access of air, upon identical lots of fruit. These differences in treatment were found to have such pronounced effects on the appearance and quality of the product, regardless of variety, that a summary of the results is necessary as a background to the presentation of the varietal comparison.

RESULTS

Effect of Type of Container. Preservation of color was distinctly better in hermetically sealed than in paper containers. In strawberries the color changes were of two general types, (1) bleaching or fading and (2) dulling or darkening toward reddish brown. The varietal material in the still frozen condition showed one or the other of these changes in widely varying degrees, but the alteration was always distinctly greater in the paper cups. In peaches, discoloration occurs as a browning of the surface, which varies widely with variety in intensity and rapidity of development. While frozen the material in the sealed cans in some varieties showed no discoloration; in others a slight browning of the top layer was apparent. In paper cups, darkening was much more pronounced and extended more deeply into the layers of fruit.

Thawing in the unopened container was not accompanied by any change in color in the sealed cans, and the odor on opening was that characteristic of the fresh fruit. Although a few varieties of peaches and a number of strawberries were satisfactory in color, odor, and flavor, when thawed in unopened paper cups, there was in most of the material considerable increase in discoloration of both fruit and sirup. Bleaching became more pronounced on thawing in many strawberries, and in many cases the normal odor and flavor were replaced by those characteristics of badly oxidized fruit.

When the containers were opened or when the frozen material was emptied into pans and thawed in the air, discoloration occurred to a degree characteristic of the variety, but that from the sealed cans generally required 3 to 6 hours to reach the degree of discoloration found in identical material in paper containers when opened after thawing.

It is obvious that these generally existing differences in behavior in the two types of container are due to the fact that the paper container permits continuous access of oxygen.

Effect of Rate of Freezing. Slow freezing was brought about by placing the packages in a room held at 16 to 18 degrees F. Six to 8 hours were required to bring the containers to a temperature of 27 degrees at the center. Those frozen rapidly with solid CO_2 reached 27 degrees at the center in about 1 hour in tin and 1¼ to 1½ hours in paper containers. The material was allowed to remain surrounded by the carbon dioxide for 16 to 18 hours but reached a minimum temperature of —80 to —82 degrees after 8 or 9 hours.

Comparisons of the two methods of freezing do not reveal any advantage accruing from rapid freezing in strawberries and peaches. On the contrary there is a distinct disadvantage in the case of some varieties of peaches packed in paper containers and subjected to rapid freezing by reason of the more rapid and extensive oxidation which accompanies thawing and injuriously affects color, odor, and flavor of the product. The writers have elsewhere suggested that this more rapid deterioration of rapidly frozen fruits may be a consequence of ice formation within the cells. No differences between rapidly frozen and slowly frozen strawberries were detected. The conclusion that very low temperatures are not necessary for the satisfactory preservation of these fruits has been independently reached by Diehl, working in the Department laboratory at Seattle, and more recently by Morris and Barker as the result of rather comprehensive comparative studies carried on at the Low Temperature Research Station, Cambridge, England, and reported in the current Report of the British Food Investigations Board.

Varietal Differences. In examining and grading the material, the factors considered were color, odor, texture, and flavor of the fruit, color and appearance of the liquid, and rate of change in these characters upon thawing and standing in air. The ranking given a particular variety was based on the appearance and quality of the material preserved in the non-air-tight paper containers, since these are the prevailing type of commercial package.

Results with Strawberries

First Rank. Five varieties stood out as distinctly superior to the others when retention of color, texture or firmness, fragrance and flavor were collectively considered. These were Big Joe, Klondike, Brandywine, Blakemore, and Redheart. Big Joe was considered somewhat the best of the five, although some of the judges also considered Redheart as outstanding. The differences between the others were too small to permit ranking them in order of merit. Seven seedlings, as yet unnamed, showed quality that appears to entitle them to place in first rank, but they are reserved for further study.

Second Rank. A number of the berries placed in this group are now being packed in some quantity in consumer packages and appear to meet with ready acceptance. Most of the varieties compared very favorably with existing commercial packs. As compared with the first group, all are distinctly inferior, being deficient in one or more of the characters requisite in a first-rank berry for freezing. In most cases the deficiency is lack of firmness, or failure to retain attractive color during and after thawing. The list does not attempt to rank varieties in order of merit. It includes Abington, Bliss, Chesapeake, Dr. Burrill, Howard 17, Portia, Missionary, Fairfax, Southland, and Belt, with about 10 unnamed seedlings that appear to rank here. Chesapeake would be almost ideal for frozen-

pack preservation were it not so light in color. Belt is an example of a variety ordinarily considered as only fair in quality but which, when preserved by freezing, is surprisingly good. Its chief defect is its lack of firmness.

Third Rank. These varieties were deficient in so many essential respects as to make them very unpromising for freezing. Most of them were flavorless and lacked distinctive character, in addition to being soft and poor in color. This group includes Aroma, Beaver, Big Booster, Bradford, Gandy, Gassett, Gene, Leman, Lupton, Pearl, Ridgely, Warfield, and about 25 unnamed selections and seedlings.

Results with Peaches

Eighteen varieties were tested, including both white- and yellow-fleshed varieties, widely grown commercial market peaches, some of the high-quality home orchard sorts, and three promising recent introductions from New Zealand, namely, A 1, Paragon, and Up-to-Date.

The ranking of the varieties is based upon the appearance and quality of the product from the non-air-tight containers. In consequence, some varieties which are placed in second rank would be placed in first rank if the hermetically sealed material were being considered, since their deficiencies are primarily due to oxidation phenomena.

First Rank. J. H. Hale, Reeves, Chairs, St. John, and Up-to-Date were distinctly superior to the other varieties in practically all points considered in the grading. All of them had good to excellent color, odor, and texture, and very satisfactory preservation of characteristic varietal flavor. There were minor varietal differences. St. John was somewhat soft, Chairs browned slightly more than the others, and J. H. Hale was especially attractive because of the bright red stippling of the flesh. All were free from any serious amount of discoloration in the paper containers, and they did not darken rapidly when opened and exposed to the air.

Second Rank. Early Crawford, Late Crawford, Slappey, and the New Zealand variety A 1, were not quite up to the level of the first group. Characteristic varietal flavor was well preserved, possibly slightly better in Early Crawford than in others, but the fruit of this variety softened somewhat more and also showed more discoloration than the others. All four showed more browning than did the first group. All were distinctly superior in appearance, color, and dessert quality to commercially packed peaches purchased on the Washington markets for comparative purposes, and would consequently fully meet existing market standards.

Third Rank. Commercial freezing of peaches in the East will necessarily make very large use of Elberta, as it is everywhere the leading variety. For this reason an especially careful study of the effect of stage of maturity upon appearance and quality of the product was made by packing fruit at various stages from shipping

ripeness on to very soft ripeness. The less mature fruit became severely discolored, had little distinctive flavor, and had an abnormal, oxidized after-taste, and was rather tough in texture. Discoloration decreased and flavor and texture improved with advancing ripeness. Extremely soft fruit made a product which was too soft. At nearly full eating ripeness the fruit preserved a fair degree of flavor and was soft and melting in texture, but was lower in dessert quality and considerably more discolored than the varieties so far named. It was equal to any of the commercial packs available for comparison and may be considered as acceptable to consumers.

Fourth Rank. The remaining varieties, Niagara, Ede, Rochester, Paragon, Carman, Hiley, Champion, and Belle, were ranked below Elberta. Each was so deficient in one or more of the characters essential to satisfactory freezing as to make it probable that they would not be acceptable to consumers. The white-fleshed varieties were somewhat badly discolored while still frozen and upon thawing they darkened rapidly and severely, were deficient in flavor, and had an abnormal, oxidized after-taste. Champion had very good texture; the other white varieties were too soft. Ede and Niagara had fairly good flavor and texture but were very badly discolored; Paragon was tough and darkened rather badly, although its flavor was fairly good; Rochester was soft in texture and lacking in flavor.

Discussion

The results thus far obtained in this study very strongly emphasize the importance of varietal behavior as a factor determining appearance and palatability in frozen-pack products. Comparatively few existing varieties possess the combination of characters requisite to production of high-grade frozen fruit. The marketability of the product will depend upon the degree to which it combines distinctive and pleasing flavor and high dessert quality with attractive color, firm but not rubbery texture of flesh, and a considerable degree of resistance to oxidation on exposure to air. Whether the distinctive flavor and dessert quality of a variety will carry through freezing preservation and reach the consumer without serious impairment can be determined only by actual experiment. This is illustrated by the behavior of the eight varieties of peaches of the Crawford or Crawford-like group herein studied. As a group they are characterized by fine flavor and unsurpassed dessert quality. Under identical treatment, Chairs, Reeves, St. John, Early Crawford, Late Crawford, and Slappey retain these characters in very satisfactory degree; Niagara and Rochester are so prone to extensive oxidation with resulting discoloration and loss of flavor, odor, and appearance as to make the product mediocre or poor.

The Temperature Factor in the Freezing Preservation of Fruits and Vegetables

By H. C. Diehl and J. A. Berry, *Frozen Pack Laboratory, U. S. Department of Agriculture, Seattle, Wash.*

INVESTIGATIONS on the response of fruits and vegetables to moderate freezing temperatures have been in progress in the Pacific Northwest since 1929. The decision to investigate the practical usefulness of preservation at these temperatures was due to considerations of a physiological nature as well as a concern for the economy involved in the mechanical refrigeration of plant products at moderately low temperatures (1,2).

The behavior of a considerable number of horticultural products has been under observation, when these were exposed to different temperatures in the range —100 to 32 degrees F as well as when they were subsequently thawed and utilized for human consumption. During 1931 and 1932, particular attention has been devoted to a study of fruit and vegetable behavior at the following air temperatures, namely, —5, 15, 20, 25, and 28 degrees F, when the various products were held in non-airtight packages as well as when they were hermetically sealed in metal or glass containers or were subjected to a variety of treatments under reduced atmospheric pressure by vacuumization or under CO_2 gas.

Several types of container were used in the experiments: (1) plain or lacquered cans of the low form, commonly designated as the frozen berry can, (2) plain or lacquered No. 2 cans, (3) cylindrical paper cups of approximately pint capacity. (4) paper cups of the low tub form, capable of holding about 1 pound of material, and (5) 16-ounce glass jars of a squat type.

Hermetic sealing of the cans was done in semi-automatic or in high-speed seaming equipment, while the glass jars were capped in a semi-automatic glass closure machine. The cups were given a roll-seal in suitable equipment designed for commercial use. The glass and metal containers were capable of vacuumization, the degree and maintenance of which, during closure in the above mentioned equipment, could be varied at will.

The freezing behavior studies at temperatures of —20 to —100 degrees F were made possible by the use of a low-temperature freezing chamber in which the refrigerating agents were solid carbon dioxide and denatured alcohol.

Among the products that have been included in these comparative freezing temperature studies are different varieties of strawberry, raspberry, blackberry, blueberry, cranberry, huckleberry, peach, apricot, prune, sour cherry, persimmon, apple, pea, bean, asparagus and mushroom.

Osmotic phenomena, prior to ice formation, in fruits exposed to sucrose and invert sirup concentration ranging from 10 to 65 per

cent, and in vegetables exposed to weak sodium chloride brine, have been studied as well as the penetration of sucrose into tissues, before as well as after their selective permeability to substances in solution had been altered by ice formation and consequent changes in the living material or protoplasm of the plant tissues. These physiological changes may profoundly alter the character of subsequent behavior of frozen plant tissues. This fact has been recognized, of course, for years, although the application of the principles to freezing preservation is a relatively recent development.

Two important principles were developed early in the experimental work, namely, (1) the variable response of different horticultural products to low temperature and ice formation, which fact suggests that specific processing data for each product will probably be necessary; and (2) the individual reaction of different varieties of the same fruit and vegetable to freezing preservation, which fact emphasized the importance of studying varietal adaptability for freezing preservation as was suggested by the senior author (1) and by Caldwell, Lutz and Moon (4).

The following specific examples may be given of the different tolerance of individual fruits to freezing temperatures Asparagus packed in brine was preserved with the fresh flavor, color, and appearance most nearly intact when frozen at —20 degrees F or below, while apples impregnated with sucrose sirup by a vacuum-sirup treatment were preserved with best color and flavor at 20 degrees F due apparently to the preservative effect of CO_2 gas evolved during respiration. A number of varieties of raspberry, strawberry, peach, and sour cherry packed in sucrose sirup, on the other hand, have been preserved to best advantage when frozen at a temperature of about —5 degrees F, while apricots showed distinctly less loss of moisture upon thawing when frozen at temperatures below —30 degrees F, a result somewhat analogous to that reported by Woodroof (5) for peaches.

The experiments have indicated that such factors as altered rate of freezing, ice formation within the plant cells, and variation in size of ice crystals under different temperature conditions may be accepted as facts, but have diminished their intrinsic importance in the behavior of plant tissues, subsequent to ice formation.

These results have been practically the same as those reported by Lutz, Caldwell and Moon (3) and by Morris and Barker (6) and are in general accordance with the theoretical discussion of the phenomenon of ice formation in plant tissues recently published by Plank (7).

Preservation of many fruits and vegetables, with practical satisfaction, is possible at temperatures centering about 0 degrees F, the essential characteristics of the moderate freezing temperature refrigeration plan being (1) reasonably rapid temperature reduction in the product, in order to preserve as much as possible its desirable qualities; and (2) the utilization of accessory factors, such as the protective or osmotic faculty of solutions in which the product is im-

mersed or the presence of reduced air pressure or inert gas in hermetically sealed containers, as aids in the low temperature preservation.

Storage at 20 and 25 degrees F seems entirely unsuitable for most plant products, packed in liquid medium such as sirup or brine and held in the various types of containers used in these experiments unless factors, not now fully understood, are given a practical usefulness by further research. For most plant products, a storage temperature of 15 degrees F seems to be the practical upper limit, insofar as autolytic product deterioration over a period of time is concerned.

The examination of many experimental samples of frozen strawberries, raspberries, blackberries, peas, and other plant products stored at —5 and 15 degrees F suggests that for most frozen products, packed in a liquid medium, there is no practical advantage in long-time storage at the lower temperature, when the cost of obtaining such low temperature is balanced against any consistent advantage in the product. In many cases, no suggestion of such advantage exists, if the selection and handling of the raw material has been proper, and in certain instances, as with some strawberry and peach varieties, there seems to be a disadvantage in such low temperature storage.

A storage temperature of 20 degrees F may be unsuitable from a physiological rather than from a microbiological viewpoint, since at this temperature, as at 15 degrees F, especially with airtight containers, CO_2 from the respiration of the fruit gives a more rapid "kill" of organisms than takes place at 0 degrees F. In a sealed can at 15 degrees F, 99 per cent of the micro-organisms may be killed in 6 months, whereas at —5 degrees F only 60 per cent may be killed in a year. A temperature of 25 degrees F may permit slow growth of certain types of fungi and bacteria, with ultimate spoilage of the material (8).

The investigations begun by the Bureau of Plant Industry for the purpose of determining the suitability of moderate freezing temperatures for the preservation of fruits and vegetables are still in progress but they have shown definitely the practical usefulness of these temperatures for many horticultural products. Satisfactory freezing preservation can be obtained therefore by means of existing cold storage facilities, with certain modifications designed to bring about rapid heat transfer from the product. Special equipment involving the use of very low temperatures does not seem to be necessary for this purpose.

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Effect of the Relative Vigor of the Vine at Planting on the Fruiting and Growth of the Concord Grape

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ABSTRACT

This paper will appear in the bulletin series of the Maryland Agricultural Experiment Station.

IN 1922, 100 one-year-old vines were classified at planting into "weak" (8 inches top growth), "medium" (15 inches top growth), and "strong" (24 inches top growth). Strong and medium vines outyielded weak vines 28 and 22 per cent, respectively, (average of 9 years) with large odds of significance. Strong vines yielded 4.8 per cent more than medium vines, a difference not statistically significant, but should be given weight when a significant difference of 16 per cent in average weight of prunings is considered. Five-year records on weight of prunings gave averages of 60.7 ounces, 52.3 ounces, and 44.9 ounces per vine for strong, medium and weak vines, respectively. Strong vines maintained more regular annual production, and there was no tendency for differences among strong, medium, and weak vines to become less in later years.

Certain Physiological Responses of Comice Pears During Cold Storage

By Fisk Gerhardt and B. D. Ezell, *U. S. Department of Agriculture, Washington, D. C.*

COMICE (Doyenne du Comice) is one of the four leading varieties of winter pears. Its smooth, thick skin and tender flesh necessitate careful harvesting and handling practices to insure freedom from bruising and subsequent fungous infection. Like the Bosc, its normal storage life depends on subjection to low temperature, preferably 30 to 31 degrees F immediately after harvesting (4). Pentzer (7), et al. have shown that temperature of 36 degrees shortens the storage life of Comice, as grown in California, from 1 to 2 months as compared with storage at 30 to 31 degrees and produces no improvement in flavor or texture of the fruit when subsequently ripened. Comice pears fail to ripen normally during storage at temperatures of 30 to 32 degrees. The variety has an average commercial storage life of 100 to 120 days when stored at 32 degrees F (5). During this period fruit will ripen normally if removed to temperatures of 65 to 70 degrees F.

Hartman (5) and also Kidd and West (6) have called attention to a peculiar physiological response that Comice, Bosc, and Hardy varieties manifested after extended storage at low temperature. The fruit appeared to have lost its normal ripening response, that is, it failed to soften and produce its characteristic color, flavor, and texture even in an optimum ripening environment. It remained hard, and green, or in extreme cases, scalded badly and showed severe breakdown at the core. We have at this time no means of predicting when the above physiological disturbance is apt to occur, since the fruit in storage appears perfectly normal upon visual inspection in spite of the fact that it may already have "gone dead" or lost its ability to ripen. So long as the above situation is true, commercial storage of Comice and Bosc, at low temperatures over extended periods, is fraught with considerable danger and often financial loss.

This report represents a preliminary study of some of the normal physiological changes in Comice pears stored at low temperatures, and an attempt to observe whether any of these changes are associated with the above storage disorder. The possibility of using certain physiological changes as an index of the approaching limit of successful storage has also been considered.

Material and Methods

Representative Comice pears were harvested in 1931; one lot was stored immediately at 32 degrees F, the remainder, in order to simulate commercial transit conditions, was delayed one week at 65 degrees prior to storage at 32 degrees. Sufficient fruit was used in each case to provide material for respiration studies, monthly samples for ripen-

ing tests, carbohydrate analyses, acetaldehyde, and alcohol determinations. The phase of the work dealing with carbohydrate analysis has not been completed to date. Respiration determinations, using a method similar to that reported by Harding, Maney, and Plagge (1), were made on 9 kilos of fruit throughout the storage period. Acetaldehyde and ethyl alcohol were determined according to the method employed by Harley (2).

Results

Total solids, pressure tests, and total acidity data are shown in Table I. It is evident that all of these values tend to decrease during

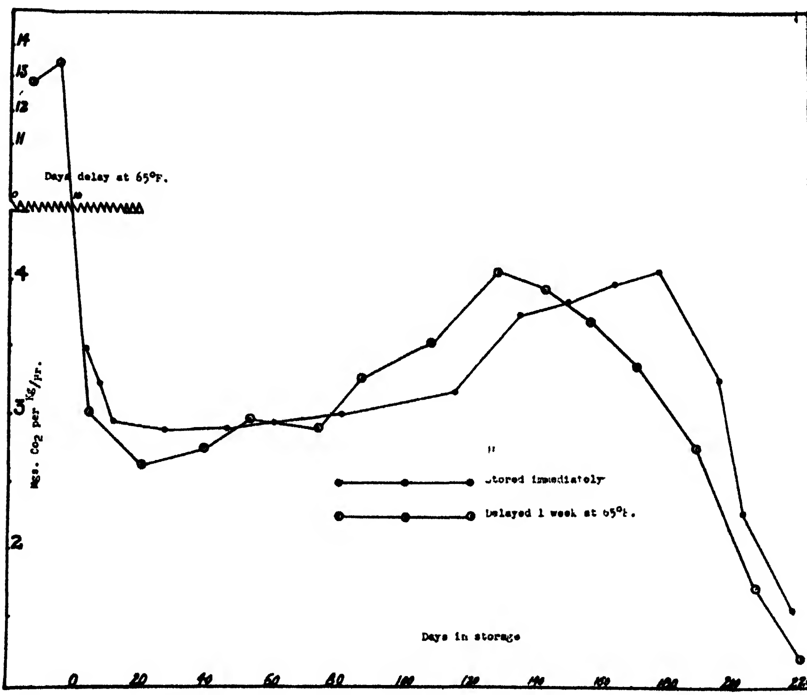

Fig. 1. Time-rate curves for respiration of Comice pears during delayed storage at 65 degrees F followed by subsequent storage at 32 degrees, and of similar fruit stored immediately at 32 degrees.

longer periods of storage. There is, however, a rather significant softening of the fruit just prior to the period in cold storage when the fruit loses ability to ripen normally. Very little change is noted in the pressure test once the fruit has "gone dead" in storage. Delayed storage apparently hastens this period by approximately 2 months.

Respiration data, as shown in Fig. 1, show some very decided physiological changes. Since the respiration rate is admittedly a criti-

TABLE I—CHANGES IN COMICE PEARS STORED AT 32 DEGREES F, IMMEDIATELY AND AFTER 1 WEEK AT 65 DEGREES F

Dates (1931–1932)	Pressure		Total Solids		Total Acidity		Remarks*	
	Stored at Once	Delayed Storage	Stored at Once	Delayed Storage	Stored at Once	Delayed Storage	Stored at Once	Delayed Storage
Sept. 18...	9.5	—	16.60	——	.167	——	1	–
Sept. 25...	—	9.2	——	16.69	——	.157	–	1
Oct. 21....	9.0	8.5	15.94	16.33	.180	.192	1	1
Nov. 21...	8.7	8.1	15.61	15.53	.201	.208	1	1
Dec. 15–16	8.9	8.4	15.29	15.08	.167	.180	1	1
Jan. 14 ..	7.8	4.7	15.54	15.59	.161	.154	1	2
Feb. 15...	5.6	4.2	14.93	14.67	.157	.154	1	3
Mar. 14...	6.2	4.8	14.97	14.52	.137	.137	3	5
Apr. 14...	6.2	4.7	15.07	14.65	.119	.117	4	6

*Remarks: (1) Fruit ripened normally. (2) Slight scald; some fruit failed to ripen. (3) Considerable scald; fruit did not ripen normally. (4) 90 per cent scald; broken down at core; no ripening. (5) 90 per cent scald; severe core breakdown. (6) Tissue completely broken down.

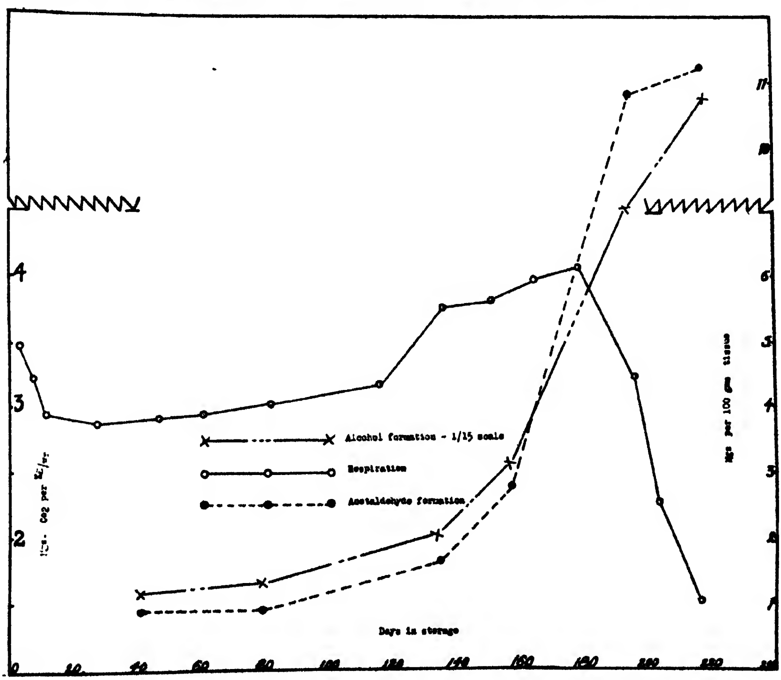

FIG. 2. Time-rate curves showing the relationship between respiration, acetaldehyde, and alcohol accumulation in Comice pears when stored immediately at 32 degrees F.

cal index of the general ripening process, Fig. 1 indicates that prolonged cold storage completely disorganizes the normal respiratory mechanism. Both delayed and immediately stored fruit failed to ripen properly just preceding the inspection of the decline in the respiratory rate. This decline in rate appears some 6 weeks to 2

months earlier in the delayed fruit, and is indicative of scald formation and general loss of normal ripening ability. It is apparent that when Comice pears are subjected to prolonged low storage temperatures, they become physiologically "dead" as far as normal respiration is concerned. The cessation in respiratory activity is reflected in a loss of the ability of the fruit to ripen normally, the two processes possibly being intimately associated.

Fig. 2 carries the physiological picture a step farther and indicates that the accumulation of certain volatile organic compounds, such as acetaldehyde and ethyl alcohol, are either causative factors or at least are closely associated with the cessation of the normal respiratory function. The fact that their accumulation in the tissue precedes the rapid cessation of the respiratory rate lends strength to the supposition that they may be causative factors. Harley (3) has also shown that the above compounds accumulate rapidly in Bartlett pears during the latter portion of their storage periods, especially during the stage when severe scald and breakdown becomes apparent. Thomas (8) has suggested that, since neither acetaldehyde nor ethyl alcohol can be oxidized by apple tissues, their presence in critical concentrations would be of diagnostic aid in cataloging certain types of physiological disorders arising from improper storage or transit conditions. The data in Fig. 2 indicates that a determination of these volatile constituents during storage, should be a valuable guide in anticipating the remaining normal storage life of the fruit.

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Transpiration Rates and Suction Forces of Fruiting Canes and Current Season Shoots of the Black Raspberry[1]

By Roy E. Marshall, *Michigan State College, East Lansing, Mich.*

THIS report is based on preliminary work in 1932 which seems to throw new light on the physiological relationship which exists between fruiting canes and current season shoots of the black raspberry. For sake of brevity, the former will be referred to as "canes" and the latter as "shoots" in the discussion.

Canes and shoots were cut, close to the crown, from Cumberland and Plum Farmer plants. The thorns were rubbed from the basal portions with a piece of ordinary wire screening. The stems were then recut under water and the excised canes and shoots taken to the greenhouse with the cut ends in bottles filled with water.

Fig. 1. Showing two canes and three shoots used in one of the late season tests.

At the greenhouse the stems were recut under water and then connected (while still under water) in series to potometers. (Fig. 1.) The water was supplied from burettes located at approximately the same level as the excised parts. Two canes were connected with one burette and two to four shoots were connected in series to a second burette, the number of shoots providing an estimated leaf area similar to that of two canes. Burette readings of water consumption were made at 15-minute intervals until five to eight readings had been recorded.

Mercury manometers were then connected with the tops of each of the burettes by heavy rubber tubing and manometer readings made at 5-minute intervals until the mercury had reached a maximum difference in the two columns and had begun to recede (a modification

[1]Journal Article No. 140 (N. S.) from the Mich. Agr. Exp. Sta.

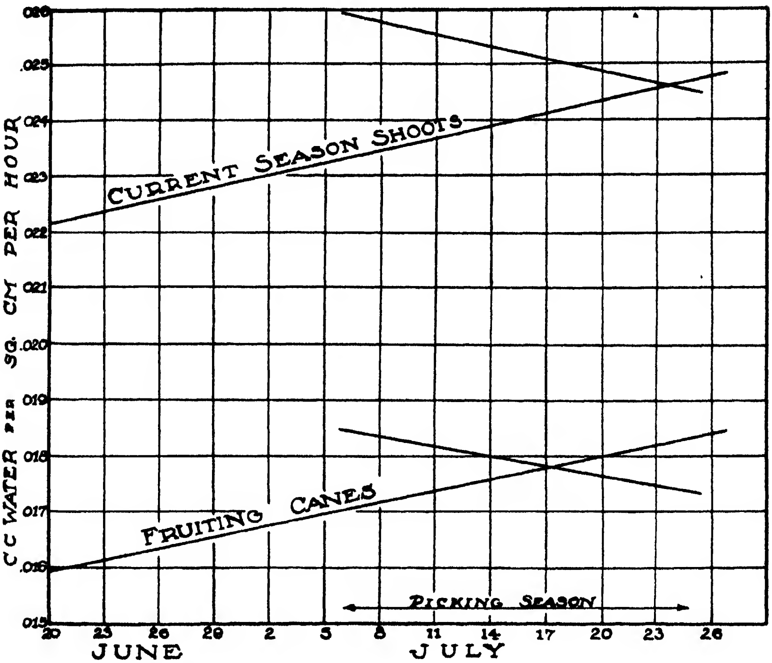

FIG. 2. Illustrating parallelism in transpiration rates for foliage of fruiting canes and current season shoots for the full season studied and for the picking season.

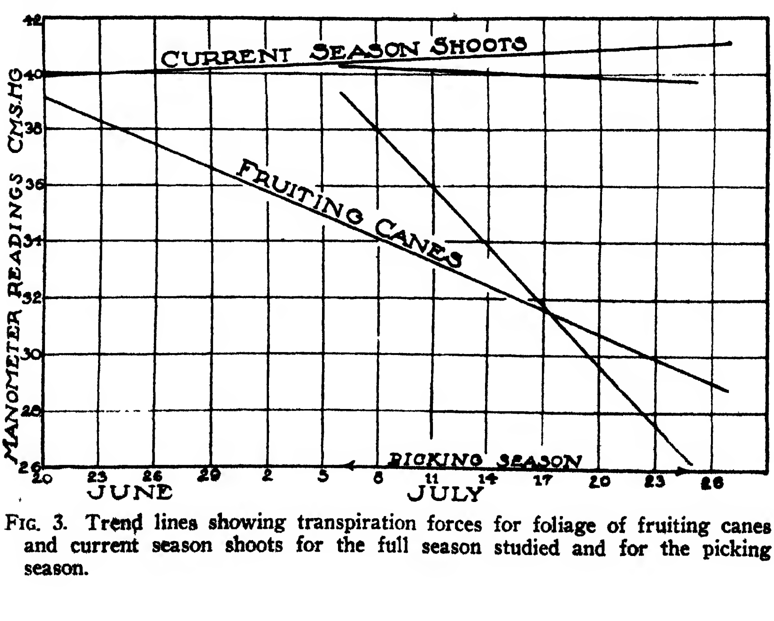

FIG. 3. Trend lines showing transpiration forces for foliage of fruiting canes and current season shoots for the full season studied and for the picking season.

of Askenasy's method for determining suction force). The maximum reading for both canes and shoots was also recorded. With the receding of the mercury, wilting of some of the leaves, particularly of the younger shoot laterals, occurred. Thick-walled rubber tubing was used throughout the system to prevent collapse, and in the case of the larger sized tubing for the connections between cane or shoot stems and glass T-tubes coiled wire was placed inside the tubing. All rubber connections were made tight by wrapping and twisting No. 20 annealed wires about them.

The data from which Figs. 2 and 3 are constructed were obtained in 23 determinations, 17 of which were made during the harvesting season.

The mean water intake per sq cm of shoot foliage per hour for the period beginning June 20 and ending July 27 was .0239 cc and that for canes was .0175 cc. In other words, the intake rate for shoot foliage was 36.6 per cent greater than that for cane foliage or the mean shoot cane transpiration ratio was 1.37. There is some indication of increases in transpiration rates for both cane and shoot foliage from June 20 to about the time of the first picking (July 6), followed by declines for both to the last picking (July 25). The number of determinations during the early part of the season, however, is too small to permit reliance on such trends. Furthermore, the error of the line is too great to justify any statement regarding trends until further work is done, possibly under more uniform temperature conditions. Brierley (1), however, noted a tendency for transpiration rates of the lower leaf surfaces of old canes to be less than those of corresponding surfaces of new canes as the season progressed and he also found a somewhat higher transpiration rate for shoots than for canes of the Latham variety. Incidentally, one test made in this study with Latham gave results similar to those here reported with the black varieties.

The significant feature of these trend lines for water intake rates of shoot and cane foliage, both for all of the season under study and for picking season alone, is that they run parallel. In other words, the mean differences in transpiration rates were constant throughout the season even though transpiration rates varied with temperature, relative humidity, and possibly other factors not apparent at this writing.

The differences in transpiration rates for canes and shoots are much greater than can be accounted for by the pulling of water from fruits. Furthermore, the differences at the end of the picking season were essentially the same as those prevailing earlier.

Comparative Suction Forces

The mean suction force or pull for shoot foliage for the full period of study was 40.6 cms of mercury. There was no appreciable change during the season under study, the trend line showing only a very slight rise with advance of the season. The readings ranged between 36 and

46 cms, or in other words, were reasonably uniform. The mean suction force for cane foliage was 32.8 cms of mercury for the season studied and it averaged 29.6 cms for 16 determinations made during the harvest season. In other words, the suction force of the shoot foliage was 37.2 per cent greater than that for cane foliage during the fruiting season. The trend line for cane foliage shows a decline of 26.4 per cent during the season under study. There was considerable fluctuation in the mercury column readings for cane foliage, the two extremes of 46 and 19 occurring only 6 days apart. However, in spite of the wide fluctuations the tendency for the cane foliage to exert less transpiration pull or force with the advance of the season appears significant and is statistically so.

On July 16 the excised canes and shoots were first tested at the usual level and then elevated 9 feet. The shoot/cane transpiration rate ratio changed from 1.08 to 1.21. On July 19 the apparatus was set up indoors at an elevation 13 feet above the floor level and the water supply lowered at intervals of ½ hour to 1 hour. Incidentally, the three shoots had practically the same foliage area as the two canes and the shoot/cane transpiration ratios per sq cm per hour were practically 1.00 until the water supply was lowered from 7 to 9½ feet when the ratio was 1.31. With the water level 11 feet below the excised plants the ratio was 7.75. At this level the shoots used 62 per cent as much water as at the zero level and the canes only 8 per cent as much. When the water level was lowered 13 feet below the plants, water began to rise very slowly in the burettes and the foliage began to wilt after some 15 or 20 minutes.

A rather rough calculation of average leaf areas per plant shows the shoots to have doubled in leaf area during the picking season while there was some decline in the leaf areas of canes due to the natural shedding of some leaves aggravated to some extent by a severe wind storm which occurred near the beginning of the picking season. At the end of the picking season the leaf area of shoots exceeded that of the fruiting canes by 30 to 35 per cent. Thus, the water requirement of shoots increases substantially with the advance of the picking season, and since the former show greater ability to pull water it is evident that a substantial change takes place in the physiological relationship between the old canes and the current season shoots.

The past season was regarded as the most favorable one for black raspberries that Michigan has experienced in several years. The late berries matured better than usual, and there was less tendency for the foliage of fruiting canes to change to the characteristic late season yellow. Whether or not the differences in the behavior of canes and shoots here described will be greater in seasons less favorable for this species cannot be foretold, but the writer will venture a guess that they will be.

Discussion

The writer (2) has shown that the differences in cane and shoot behavior noted in this paper cannot be attributed to differences in osmotic concentration of the foliage or to differences in the conductive capacities of the canes and shoots. Since the shoot foliage has a higher water intake rate than cane foliage and since the amount of shoot foliage on the average plant in the plantation which supplied this material increased as much as 100 per cent during the fruiting season, it seems possible that the water requirement of the shoots may be such as to inhibit the proper development of fruit on the less vigorous canes during the latter portion of the fruiting season. The data also indicate that the fruiting canes cannot compete with shoots in obtaining an optimum supply of water from droughty soils or under conditions of stress, especially near the end of the fruiting season.

It is again emphasized that the results herein reported are preliminary and that any conclusions must be regarded as tentative. Furthermore, transpiration as measured by the potometer expresses what the leaves will transpire with a free and uniform supply of water and does not necessarily reflect what they actually transpire on the plant.

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The Effect of Removal of Fruiting Canes After Harvest Upon the Growth of New Canes in the Latham Raspberry[1]

By W. G. BRIERLEY, *University of Minnesota, St. Paul, Minn.*

A STUDY of the effects of removal of the fruiting canes immediately after the close of the harvest season upon the growth and maturity of the new canes was carried on in 1932.

In a plot of the Latham variety growing in clay loam soil, 50 apparently normal hills were selected at random and identified by number. The old canes were removed from the odd-numbered hills on August 3, and allowed to remain in place in the even-numbered hills. Four apparently normal new canes in each hill were identified by means of numbered tags and measured each week until September 22, when growth had ceased. Thus, at the beginning of the study there were 100 new canes in each treatment.

The number of canes was considerably reduced by the end of the growing season, the losses being due mainly to the snowy tree cricket. This insect damaged about 30 per cent of the canes, as far as growth measurements were concerned, by feeding upon the growing tips. Altho this injury occurred throughout the period of observations it was most severe during the week of August 18 to 25. This injury may be considered of little importance from the standpoint of fruit production as the canes averaged more than 160 cm in height before the first injury was noted. Other canes were lost by wind breakage at the point of the scars formed by the egg clusters of this insect and a few were lost because of cane borers. When the last measurements were made on September 22, there were 57 normal canes remaining in the pruned hills and 63 in the unpruned hills.

Differences in the behavior of the canes in the individual hills were noted as the season progressed. Most of these differences apparently were due to the usual variations in growth, but the most marked differences were due to the early formation of terminal buds. One or two terminal buds were formed as early as August 11 in the unpruned hills and on August 18 in the pruned hills. At the end of the season there was a slightly larger proportion of this type of cane in the unpruned hills, but the number in each case was approximately the same as in other fields of the Latham variety in which about 5 per cent of the new canes were of this type.

The average growth rates for the two treatments are shown in Table I. These data indicate that with the old canes not removed the growth rate of the new canes declined steadily and growth ceased about September 8. In the hills from which the old canes had been removed the growth rate of the new canes was more rapid and showed no decline until after August 25. These canes continued to grow for

[1]Paper No. 1163 of the Journal Series of the Minnesota Agricultural Experiment Station.

a week after growth had ceased in the unpruned hills, although the decline in growth rate in the latter part of the season closely paralleled that of the other treatment.

TABLE I—AVERAGE GROWTH RATE OF NEW CANES WITH AND WITHOUT REMOVAL OF OLD CANES (GROWTH SHOWN AS CENTIMETERS PER WEEK)

Date	8/11	8/18	8/25	9/1	9/8	9/15	9/22
Old canes removed...........	9	9	9	6	4	2	0
Old canes not removed	7	6	5	4	2	0	0

The effect of the removal of the old canes on the average length of the new canes is shown in Fig. 1. The 57 new canes growing in the hills from which the old canes were removed on August 3, grew on the average somewhat more rapidly and somewhat longer than the 63 new canes in the unpruned hills. Although the differences in cane length are not statistically significant they are of interest in that they indicate the possibility of the raspberry plant utilizing in the growth of the new canes the water and mineral foods which otherwise would have been taken up by the old canes.

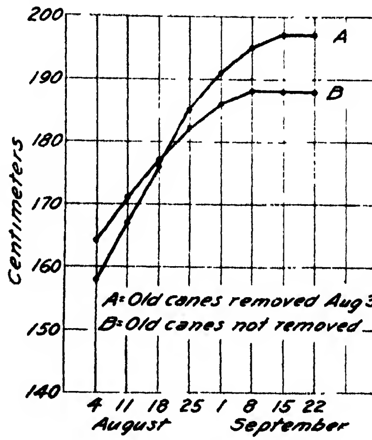

FIG. 1. Growth of new canes with and without removal of old canes.

As the weather conditions in the latter part of September and in October were favorable for the complete maturing of the new canes in both treatments there was no apparent difference between the two treatments in late October. The later growth following the removal of the old cane may be undesirable in some seasons. In Minnesota late cane growth which is poorly matured sometimes is severely injured by early hard freezes. Altho the removal of the old canes after harvest may be desirable at times as a means of pest control or moisture conservation, the effects upon growth and maturity should not be overlooked.

Nitrogen Fertilization of Latham Red Raspberries[1]

By W. H. Childs and M. B. Hoffman, *West Virginia University, Morgantown, W. Va.*

In the spring of 1929, studies of fertilizer requirements of red raspberries were started in a 2-year-old field of Latham at the Horticultural Farm, Morgantown, West Virginia. The field comprised approximately ⅓ acre and consisted of 10 hedge rows 238 feet long and 7 feet apart. Prior to the setting of the plants an application of superphosphate at the rate of 300 pounds per acre had been made. A cover crop of soybeans had been turned under in the fall of 1926. Other than this no fertilizer treatment had been provided during the first two seasons. The soil is the Dekalb type, which is rather common in northern West Virginia and medium to poor in fertility. The area is level, except for three rows on the south side which have a gentle slope.

Careful studies of growth variations while the plants were still dormant in the spring of 1929 showed that the seven rows on the north side of the field were noticeably better in stand and cane growth than were the three rows on the slope. This indicated that the leaching of plant nutrients had been greater on the south side. These seven best rows were not so uniform in stand and growth as one would desire for further studies, but from a commercial standpoint this field would be considered very uniform.

The method of laying out this experiment was fully explained in a previous paper (1) and will be mentioned but briefly here. Yield records were kept in 1929, and the field was divided into forty 50-foot plots with a 4-foot margin at each end of the row and a 10-foot length intervening between each two plots. Thirty-six of these plots were then divided into six groups on the basis of 1929 yields. The groups were designated A, B, C, D, E, and F, and corresponding plots were paired and labeled A^1—B^1—C^1—D^1—E^1—F^1, A^2—B^2, etc., so that Student's Method of odds for paired experiments could be used in analyzing the data. Correlation studies, which have shown a coefficient of correlation of 0.5657 ± 0.0775 between plot yields for 1929 on which the layout was based, and total plot yields for the 3 years 1930–32, indicate that the use of Student's Method in interpreting these results is permissible.

Since nitrogen is commonly believed to be the limiting element in raspberry production,[2] this project was designed entirely to compare quantities and time of application of a nitrogenous fertilizer (Fig. 1). The treatments were as follows: A—Fall check (50 pounds $NaNO_3$ per acre), B—200 pounds $NaNO_3$ per acre applied in the fall, C—

[1]Published with the approval of the director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 124.

[2]Stene (2) in recent studies found potassium to be more limiting than nitrogen under Rhode Island soil conditions.

300 pounds $NaNO_3$ per acre applied in the fall, D—Spring check (50 pounds $NaNO_3$ per acre), E—200 pounds $NaNO_3$ per acre applied in the spring, and F—300 pounds $NaNO_3$ per acre applied in the spring. The fall application was made during the second week in September and the spring application during the second week in April.

1	C^6	11	Out	21	C^4	31	E^1
2	F^4	12	B^5	22	F^1	32	D^3
3	C^1	13	E^5	23	A^4	33	B^3
4	F^5	14	D^6	24	A^6	34	C^2
5	A^5	15	F^6	25	D^4	35	C^3
6	B^4	16	D^5	26	A^2	36	F^2
7	Out	17	A^1	27	E^2	37	F^3
8	B^6	18	Out	28	B^2	38	A^3
9	D^1	19	Out	29	E^6	39	C^5
10	B^1	20	E^3	30	E^4	40	D^2

FIG. 1. Layout of fertilizer experiment.
Fall applications of $NaNO_3$: A, 50 pounds; B, 200 pounds; C, 300 pounds.
Spring applications of $NaNO_3$: D, 50 pounds; E, 200 pounds; F, 300 pounds.

The entire field received the same cultural treatment with the exception of $NaNO_3$ applications. No other fertilizer was applied. Cultivation was carried on from early spring until harvest, and a cover crop of oats was sown shortly after harvest. Very few of the canes reached a height of over 60 inches, so it was unnecessary to do any pruning.

Yield records were kept in 1930–32. A record of the number of canes was taken in each plot during the winter of 1931, and of the cane diameter and length of a random sample of 50 canes.

RESULTS AND DISCUSSION

The results of the different treatments on yield and on number, height, and diameter of canes are given in Table I, and the significance of the variations in yield are shown in Table II. In Group E (200 pounds $NaNO_3$ applied in the spring), E^3 gave yields so far below all other plots that it was discarded. The corresponding plots in the pairing—D^3 and F^3—were omitted when necessary in analyzing the data. Locust injury to the young shoots during the summer of 1931 combined with winter injury and a dry season in 1932 cut the yields decidedly for 1932.

Both 200-pound and 300-pound applications of nitrate of soda applied either in the spring or in the fall increased the total yield over that of the check plots. However, the increases due to the 200-pound applications were not sufficiently consistent to be significant, giving odds of only 2.18 to 1 and 7.55 to 1 for fall and spring appli-

cations, respectively. Both the fall and spring 300-pound applications, in contrast, gave significant odds over their respective checks, 66.1 to 1 in the first case and 35.8 to 1 in the second case. The increases in yield of the 300-pound blocks over the 200-pound blocks in both spring and fall were also significant. While the 300-pound fall application gave a total yield 1206 quarts above the corresponding

TABLE I—YIELD AND WOOD PRODUCTION DATA

Group	Application (Pounds $NaNO_3$)	Yield per Acre (Qts.) 1929	1930	1931	1932	Total 1930–1932	Number Canes per A. 1931	Average Height (Inches) 1931	Average Diameter in 32nds of an inch 1931
A	50, Fall	2216	2808	4838	2857	10504	28020	43.93	10.26
B	200, Fall	2248	3056	5021	2945	11021	29057	41.07	10.04
C	300, Fall	2255	3813	5759	3803	13375	32914	43.19	10.28
D	50, Spring	2242	2766	4805	2707	10279	25510	43.89	10.33
E*	200, Spring	2371	3076	5274	3427	11778	30938	44.84	10.60
F	300, Spring	2222	3417	5492	3259	12169	30716	45.90	10.65

*E^1 was so decidedly low that it was ignored in calculating the results given. Since this pairing was the lowest in the original layout, the results given for E are somewhat high.

TABLE II—SIGNIFICANCE OF FERTILIZER TREATMENTS WITH $NaNO_3$

Treatments Compared	Mean Difference (Ozs.)	Student's Odds
200 lbs.—Fall to Fall check (50 lbs.)	+ 99.8	+ 2.18
300 lbs.—Fall to Fall check (50 lbs.)	553.8	66.10
300 lbs.—Fall to 200 lbs.—Fall	454.0	63.06
200 lbs.—Spring to Spring check (50 lbs.)	282.8	7.55
300 lbs.—Spring to Spring check (50 lbs.)	550.4	35.8
300 lbs.—Spring to 200 lbs.—Spring	267.6	> 4999.0
Fall check (50 lbs.) to Spring check (50 lbs.)	43.3	<1.40
200 lbs.—Fall to Spring check (50 lbs.)	143.2	3.61
300 lbs.—Fall to Spring check (50 lbs.)	597.2	253.40
200 lbs.—Fall to 200 lbs.—Spring	—148.6	—64.46
300 lbs.—Fall to 300 lbs.—Spring	232.7	8.38

spring application, the odds were not significant. The 200-pound spring application gave odds of 64.46 to 1 over the corresponding fall application.

In analyzing the yield data, one point was noticed that apparently has some bearing on the results even though it was not intended as a part of the experiment. Four plots which were not included in the fertilizer grouping received no fertilizer during the 4 years 1929–32. The mean yield for these plots for 1929, when the experiment was laid out, was 344.75 ounces as compared to 435.06 ounces for the rest of the field. The mean yield for the combined totals for 1930–32, for these four plots was only 1130.5 ounces as compared to 2220.60 ounces for the rest of the field and 2004 ounces for the checks which received 50 pounds $NaNO_3$. This seems to indicate that the yields for the check plots are considerably higher than would be the case if no $NaNO_3$ were applied to them.

Correlation studies of yield and wood production show that the number of canes is quite highly correlated with yield, giving a coefficient of correlation of 0.5940 ± 0.0728. Cane length and cane diameter show less correlation to yield, giving coefficients of 0.471 ± 0.0875 and 0.386 ± 0.0956, respectively. A product obtained by multiplying the number of canes by the length by the diameter shows a coefficient of correlation of 0.633 ± 0.0647 when compared to yield.

The foregoing data indicate that the application of 300 pounds of $NaNO_3$ per acre either in the fall or spring on a soil of poor to medium fertility will cause a significant increase in the yield of the Latham red raspberry. No consistent advantages of spring application of nitrates over fall application, or vice versa, were shown. It is probable that, had the yield records for 2 or 3 years rather than for 1 year been used in laying out the experiment, the increase following 200-pound applications of $NaNO_3$ would have been significant. Correlation studies show that much of this increase results from greater wood production in the fertilized plots, number of canes being the outstanding factor in increased wood production.

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Seasonal Tests of the Fruits of Various Raspberry Varieties[1]

By Lowell R. Tucker, *University of Idaho, Moscow, Ida.*

A STUDY was made in 1932 of the size, firmness, and juice concentration of red and black raspberry fruits ripening at intervals throughout the harvest season. The plants were grown near the base of a western slope on Palouse loess soil at the University Station, Moscow, Idaho. The season began with plenty of moisture in the soil; however, there was very little summer rainfall. During the 2 weeks before July 15 when harvest started there were two rains, one on July 3 of 0.45 inch and one on July 13 of 0.02 inch. During harvest there was a trace of rain on July 18 and 0.01 inch on July 28. The berries were produced without irrigation during this fairly dry summer which may have caused them to show a different test than would fruit grown in a more humid climate. The varieties are comparable, however, since all received the same treatment.

Methods

At the time commercial pickings were made, a random sample of ripe fruit was obtained for each test. Size was measured by weighing a counted number of fruits and calculating the average weight per berry.

Firmness was determined by the following method: A 250 cc graduated cylinder was filled with fruit, dropped a distance of 8.3 cms. 10 times and the resulting height read, then dropped 40 times more and the height read again. This method is based on the principle worked out and used by H. C. Diehl, United States Department of Agriculture, and H. D. Locklin, Western Washington Experiment Station.

The fruit used in the firmness determination was next crushed, mixed, and the juice extracted by draining through a fine tea strainer with 28 wires per inch each way. This juice was immediately tested for percentage of soluble solids, using the Zeiss refractometer. Between repeated random samplings of fruit the variations of solids in the juice averaged 0.35 per cent for red raspberries and 0.50 per cent for black raspberries. The refractive index of the juice of black raspberries was hard to read due to the indefinite line produced.

The efficiency of the Zeiss industrial refractometer in determining soluble solids was measured by testing samples of juice in the following manner: First, the refractive index was read; next, the sample of the juice was weighed; then dried in an oven at 55 to 65 degrees C for 40 to 48 hours and again weighed. Black raspberry samples were washed with water to separate enough juice from the pulp for the

[1]Published with approval of the Director as Research Paper No. 91 of the Idaho Agricultural Experiment Station.

drying test. The results (Table I) show that the two methods did not vary more than 0.4 per cent in any case and that the average variation was only 0.125±0.23 per cent, which is more accurate than the random sampling as shown in the previous paragraph. This shows the refractometer method to be accurate in determining the percentage of soluble solids in raspberry fruit juice. The great saving in time makes the instrument very efficient and, since soluble solids in the juice are mostly sugars, satisfactory for testing this quality.

TABLE I—A COMPARISON OF REFRACTIVE INDEX OF RASPBERRY JUICE AND ITS DRY WEIGHT IN PER CENT

Variety from Which Juice was Taken	Sample No.	Refractometer Reading (Per cent)	Fresh Weight of Juice (Gms)	Dry Weight of Juice (Gms)	Dry Weight of Juice (Per cent)	Variation from Refractometer Readings
Latham	1	12.5	8.200	1.020	12.4	—0.1
Latham	2	12.7	4.820	0.610	12.7	0.0
St. Regis	1	13.6	3.400	0.470	13.8	+0.2
St. Regis	2	13.5	5.180	0.680	13.1	—0.4
Kansas and water	1	8.4	17.940	1.440	8.0	—0.4
Kansas and water	2	8.2	14.730	1.240	8.4	+0.2
Cumberland and water	1	10.5	14.030	1.445	10.3	—0.2
Cumberland and water	2	9.8	23.550	2.240	9.5	—0.3
Average						—0.125±.229

PRESENTATION OF DATA

Size of Fruit: At each picking a counted number of berries of each variety (Table II) was weighed and the average size per berry determined. The size of the ripe berries of both the red and black groups diminished as the season progressed until finally they were about 15 to 20 per cent smaller than at the first picking.

The red varieties differed considerably in average size of fruit. Latham berries weighed 2.1 grams, almost twice as much as St. Regis, while Cuthbert (1.5 grams) and King (1.4 grams) ranged in between (Table II). The three blackcaps were larger than St. Regis but smaller than the other reds. All three blacks were about the same size, with Cumberland measuring slightly largest, Kansas second, and Gregg third. Gregg ripened slightly the earliest while Kansas was latest, having no ripe fruit at the first picking.

A comparison was made of the number of seeds per fruit and of the relative amount of fruit per seed. Fifteen fruits were weighed separately on milligram scales and the number of drupelets in each aggregate fruit counted. These data were then plotted on Fig. 1.

Fig. 1 was constructed so that the vertical lines designate the number of drupelets in a berry, the horizontal lines the berry weight in milligrams, and the diagonal lines the average weight of the drupelets. Each berry of a red variety was next located on this chart according

TABLE II—AVERAGE BERRY WEIGHT IN GRAMS OF VARIOUS VARIETIES MEASURED AT DIFFERENT HARVEST DATES

Date Tested	7–15		7–18		7–22		7–26		7–29		
Variety	No. Weighed	Wt. Per Berry (Gms)	No. Weighed	Wt. Per Berry (Gms)	No. Weighed	Wt. Per Berry (Gms)	No. Weighed	Wt. Per Berry (Gms)	No. Weighed	Wt. Per Berry (Gms)	Average Weight (Gms)
Cuthbert	157	1.35	104	1.72	140	1.51	189	1.43	95	1.36	1.47
Latham	61	2.48	87	2.38	90	2.02	114	2.08	99	1.74	2.14
St. Regis	145	1.27	122	1.26	200	1.11	196	1.01	126	1.04	1.14
King	137	1.44	130	1.35	137	1.39	176	1.46	124	1.32	1.39
Cumberland	98	1.79	145	1.36	162	1.21	236	1.16	160	1.14	1.33
Gregg	155	1.16	151	1.35	119	1.30	217	1.21	114	1.04	1.21
Kansas			116	1.62	145	1.18	225	1.13	132	1.08	1.25
Av. of red varieties		1.64		1.68		1.51		1.50		1.36	
Av. of black varieties				1.33		1.23		1.17		1.09	

to its weight and number of drupelets and lines then drawn to connect each point with the average of the 15 berries. The berries of the different black varieties were nearly the same in number of drupelets and in size. This caused the lines leading from the individual tests to overlap extensively and only the averages are shown.

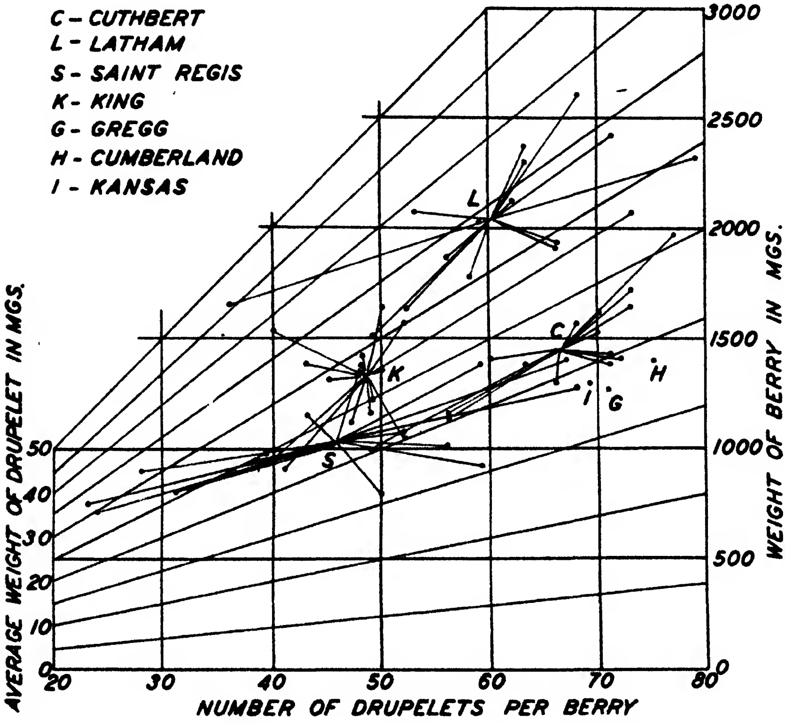

FIG. 1. Size of Berry, Number of Drupelets and Average Size of Drupelets in Various Raspberry Varieties.

It is of passing interest to note how nearly the average size of the 15 fruits of each variety parallel the average size for the season as shown in Table I. Five berries of each lot were tested on July 19, and 10 on July 27. This seems to be a fairly accurate distribution for the season.

Fig. 1 shows fewer drupelets per fruit in the four red than in the three black varieties. Of the red varieties (see also Table III), Cuthbert is larger than St. Regis, because its drupelets which are approximately the same size are more numerous. King is about one-sixth larger than St. Regis, mainly because of larger drupelets. King, although slightly smaller than Cuthbert, has only about three-fourths as many drupelets which are each about one-fifth larger. King, therefore, has fewer seeds per pound of fruit than do either St. Regis or Cuthbert. Latham, the largest-fruited variety of the lot, also produces the

largest drupelets. Its drupelets are about 50 per cent larger than those of Cuthbert and St. Regis. Compared to Cuthbert the larger size of Latham is due entirely to its larger drupelets since it has even fewer than does the former variety. It is larger than St. Regis and King because it produces both larger and a greater number of drupelets.

TABLE III—Red Varieties Ranked According to Number and Size of Drupelets and Size of Berry

Rank	Largest 1	2	3	Smallest 4
Size of berry	Latham	Cuthbert	King	St. Regis
Size of drupelet	Latham	King	St. Regis	Cuthbert
Number of drupelets	Cuthbert	Latham	King	St. Regis

The three black varieties, Cumberland, Gregg, and Kansas, each have about the same average size of drupelet, but Cumberland has a few more per berry and is therefore slightly larger. These three as a group have a larger number of small-sized drupelets than do any of the reds (Table IV). Any enlargement in size of drupelets to increase the size of berry would be expected to decrease the percentage waste as seed and crude fiber, since there is only one seed in each drupelet.

Table IV also shows data reported by Darrow and Sherwood (1), as to the average berry weight and size of drupelets produced by the Cuthbert (red) raspberry near Corvallis, Oregon, in 1931. As compared with the local fruit the coastal-grown Cuthbert had 29 per cent more drupelets each of which was 50 per cent larger, making it almost twice the size.

TABLE IV—Variety Comparison of Berry and Drupelet Size

Variety	Av. Berry Wt. (Gms)	Av. Number Drupelets per Berry	Av. Drupelet Wt. (Milligrams)	Av. Number Seeds per Gram of Berry
Cuthbert (Darrow)	2.80	85.2	33	30.4
Cuthbert	1.447	66.2	22	46.0
Latham	2.042	60.1	34	29.4
St. Regis	1.039	45.7	23	44.0
King	1.333	48.1	28	36.1
Cumberland	1.401	75.2	19	53.7
Gregg	1.272	70.7	18	55.6
Kansas	1.292	69.3	19	53.6

Firmness of Fruit: Readings were taken after the 250 cc graduated cylinder of fruit had been dropped 10 times at each test, and again after being dropped 50 times, as explained under "Methods." The averages of the two readings give a smoother curve than either alone and are therefore used as a more accurate measure of firmness.

There was little difference in firmness between the four red varieties, although they varied markedly in number of drupelets and in size of both drupelets and berries. The Cuthbert, Latham, and St.

Regis each matured both firmer and smaller berries as the season advanced, while the King changed little in either respect. There was very little difference in firmness between the black varieties. They

TABLE V—AVERAGE FIRMNESS OF VARIOUS VARIETIES MEASURED AT DIFFERENT HARVEST DATES

Date Tested	7-18	7-22	7-26	7-29	Average
Variety					
Cuthbert	154	164	166	182	166.5
Latham	159	160	163	186	167.0
St. Regis	160	168	180	179	171.8
King	174	157	169	170	167.5
Cumberland	190	196	174	168	182.0
Gregg	209	195	179	171	188.5
Kansas	198	186	182	163	182.2
Average:					
Red varieties	162	162	170	179	
Black varieties	199	192	178	167	

matured smaller berries as the season progressed which, unlike the red varieties, became softer. Early in the season the black varieties were firmer than the red, but finally with the development of softer fruits in the former and harder fruits in the latter there was little difference between the two. This makes the season average for the black varieties firmer than for the red, due undoubtedly to factors other than size of drupelet or berry.

Soluble Solids: Tests of soluble solids in the juice of fruit harvested at different dates showed some variation but in the case of the

TABLE VI—SOLUBLE SOLIDS OF VARIOUS VARIETIES AT DIFFERENT PICKING DATES. REFRACTOMETER READINGS OF JUICE IN TERMS OF PERCENTAGE

Date	7-15	7-18	7-22	7-26	7-29	Average
Variety						
Cuthbert	13.9	14.2	14.9	13.3	14.5	14.2
Latham	12.0	11.8	11.8	11.2	11.3	11.6
St. Regis	11.6	12.7	13.8	11.0	12.8	12.4
King	12.5	13.3	14.6	12.9	13.6	13.4
Cumberland	15.8	16.1	21.0	18.9	21.5	18.7
Gregg	16.0	16.9	18.7	18.0	21.8	18.3
Kansas	†	*	17.7	18.6	21.8	
Average:						
Red varieties	12.5	13.0	13.8	12.1	13.0	
Black varieties	15.9	16.5	19.1	18.5	21.7	

†Not ripe.
*Not recorded.

four red varieties there was not a dependable seasonal trend (Table VI). The juice concentration was lowest in the Latham with 11.6 per cent average, next in St. Regis (12.4 per cent) with +0.8 ± .28 increase. King with 13.4 per cent was 1.8 ± .24 higher than Latham and 1.0 ± .07 above St. Regis. Cuthbert had the highest juice concentration of the red varieties with 14.2 per cent, which was 2.6 ±

.16 higher than Latham, 1.8 ± .14 more than St. Regis and 0.8 ± .13 above King.

The percentage of soluble solids increased markedly during the harvest period in the blacks with no significant difference between the varieties. During the same period they ripened smaller, softer berries. Apparently the percentage of soluble solids in the juice of this group was related to the firmness of the fruit. The percentage of soluble solids in the reds remained about constant as the season progressed while their fruits became smaller and firmer.

The readings on July 26 show a general decline of soluble solids for each variety. The daily mean temperature dropped from July 22 to July 26, which may be an explanation or just a coincidence.

Conclusions

Size of fruit varied markedly between varieties. The late-maturing berries were smaller than those ripening earlier in each variety tested except King.

The early pickings of the black varieties were firmer than of the reds. The later-maturing fruits of the former group became softer, while those of the latter group were firmer, until at the end of the season the black varieties were fully as soft as the reds.

The refractometer was found to be an accurate, rapid method of determining the percentage of soluble solids in raspberry juice. Early in the season the juices of the black raspberry fruits contained a higher percentage of soluble solids than did the red fruits. The later-maturing fruits of the red group did not increase the percentage of soluble solids in their juices, while those of the black group did. This made a much larger difference between the two groups at the end of harvest than at the beginning in favor of the black.

In the black group a negative relationship existed between the firmness of the fruit of a variety and the percentage of soluble solids of its juices. As the berry size of the red group decreased, firmness increased.

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Influence of Nitrogenous Fertilizers Applied at Different Dates on the Numbers of Flower Clusters, Flowers, and Fruits of the Strawberry

By R. W. Taylor, *Alabama Polytechnic Institute, Auburn, Ala.*

LARGE amounts of nitrogenous fertilizers are commonly applied as topdressings in winter to matted-rows of strawberries in all sections of Alabama. Experiments were conducted to determine the best date for the application.

An experiment in south Alabama in 1930(1) showed that the numbers of flowers and fruits were increased by nitrogen applied in January of the fruiting year. In 1931(2) nitrogenous fertilizer was applied to the Missionary variety at different dates before the fruiting season. Where nitrogen was supplied to vigorous plants on January 20, there was an increase in the number of flowers over that of the unfertilized plants 55 days later. The plants fertilized January 20 matured more berries early in the season than those fertilized later. Applications February 20 or March 20, increased only the late crop, that is, those ripening after May 12.

The fact that about 2 months elapsed from the date of treatment until increased flowering, due to the fertilizer, suggested that the increased number of blossoms was due to the opening of buds on flower clusters differentiated after the material was applied. Waldo (3) found a range of 48 to 67 days, with different varieties, from the date of first definite differentiation of the fruit-bud until the primary flower was open, or ready to open, in the fall.

According to Darrow and Waldo (4), "In Florida the varieties there evidently initiate fruit-buds continually throughout late fall, winter, and spring, as flower cluster production is a continuous process from November until June. From Georgia to North Carolina winter temperatures are cold enough to enforce short dormant periods but the fruit-bud formation of fall is again resumed as soon in the spring as temperatures become high enough for growth." Growth in south Alabama is practically continuous during winter while normally in north Alabama the plants appear to be nearly dormant during a considerable period.

Experiments were started in the fall of 1931 to determine the effects of nitrogenous fertilizer, applied at different dates, on the numbers of flower clusters, flowers, and fruits produced. The winter of 1931–32 was unusually mild, and plant growth and blossoming occurred in all sections of the state throughout most of the winter. The results herein reported indicate the effect on fruit-bud production that may be expected when winter temperatures are sufficiently high for plant growth.

1. Plants were set in field bins of Norfolk sand at Auburn in November, 1931. Adequate amounts of phosphate and potash were applied to the soil before the plants were set. Nitrogen, 30 pounds

per acre, derived from cottonseed meal and from urea, was applied at different times in 1932 before the fruiting season. Table I.

TABLE I—INFLUENCE OF NITROGEN FERTILIZERS APPLIED AT DIFFERENT DATES ON THE NUMBERS OF FLOWERS, FRUITS, AND FRUIT CLUSTERS OF KLONDIKE STRAWBERRIES PRODUCED IN 1932 ON NORFOLK SAND AT AUBURN, ALABAMA. CORRECTED FOR STAND

Date Nitrogen[1] Applied	Average[2] Number per Plot					
	Flowers		Fruits		Fruit Clusters	Fruits per Cluster
	to Mar. 26[3]	Mar. 26–Apr. 22	to May 9	to May 22		
Jan. 1, 1932....	48	99	39	67	24	2.7
No nitrogen....	11	36	18	34	17	1.9
Feb. 1, 1932 ...	14	50	23	55	20	2.7
No nitrogen ...	7	30	16	34	16	2.1
Mar. 1, 1932...	6	31	15	40	16	2.3
No nitrogen.. .	7	24	12	30	16	1.7

[1]Nitrogen derived from cottonseed meal and from urea, applied at the rate of 30 pounds per acre.
[2]Average of eight plots of 15 plants each.
[3]Killed by cold.

The greatest numbers of flowers and fruits were on plots where nitrogen was applied January 1, while plots fertilized on March 1 produced fewer flowers and fruits than those fertilized February 1. The number of berries per cluster was increased in all cases by the application of nitrogen. Plants fertilized January 1 indicated, by the appearance of foliage later in the season, that additional nitrogen was needed. Soil tests showed only traces of nitrate nitrogen in these plots on April 7, as compared with a moderate to heavy supply where the nitrogenous materials were applied February 1, 1932.

Sections of matted-rows at Auburn were also fertilized on February 1 and March 1, 1932, respectively, with sulfate of ammonia and compared with unfertilized plants. The plants had received very little fertilizer in 1931 and consequently were comparatively weak. The flowering was increased, due to the fertilizer treatments in the fruiting year, about 3 weeks after the application was made. This initial increase was apparently due to the opening of weak flower buds that would not otherwise have opened. Later in the season, there was an additional increase in the number of flowers due to an increased number of flower clusters on the fertilized rows.

2. A planting was made at Brewton, Alabama, in November, 1931, on Norfolk fine sandy loam. Nitrogen was applied at different dates before fruiting in 1932, 30 pounds per acre, from a mixture of nitrate of soda and sulfate of ammonia. The production of flowers and fruits is shown in Table II.

Plants fertilized on January 9, 1932, had more open flowers than the check plants when the blossom record was started on March 22, while at this time plants fertilized on February 1 and March 4 had

fewer flowers than the checks. Plants fertilized on February 1 began to show an increase in number of flowers over that of check plants 59 days later.

TABLE II—FLOWER AND FRUIT PRODUCTION OF KLONDIKE STRAWBERRIES ON NORFOLK FINE SANDY LOAM AT BREWTON, ALABAMA, AS INFLUENCED BY NITROGENOUS FERTILIZER[1] APPLIED AT DIFFERENT DATES IN 1932

Date of Flower Count	Av.[2] No. Open Flowers from Fertilizers Applied				Date of Fruit Count	Av.[2] No. Fruits Produce from Fertilizers Applied			
	None	Jan. 9	Feb. 1	Mar. 4		None	Jan. 9	Feb. 1	Mar. 4
Mar. 22...	19	26	15	11	Apr. 23[3]...	77	104	77	72
Mar. 30 ..	14	26	17	11	Apr. 30....	88	153	106	78
Apr. 8....	30	55	34	23	May 7 ...	104	113	95	99
Apr. 15...	35	59	43	35	May 14....	99	78	84	99
Apr. 22...	65	93	77	58	May 21....	32	24	25	24
May 1 ...	38	50	52	38	May 28....	63	62	56	57
May 6....	21	33	30	33	June 4	42	44	39	30
Total...	222	342	268	209	Total. .	505	578	482	459

[1]A mixture of nitrate of soda and sulfate of ammonia applied at a rate to supply 30 pounds of nitrogen per acre.
[2]Average of four plots of 25 plants each.
[3]Total berries produced prior to April 23 given rather than number for preceding week.

Plots fertilized January 9 produced more early berries and a greater total crop than the others, while plants fertilized in March produced the smallest number of fruits. The average weight per berry was highest (3.35 grams) where nitrogen was applied in January and lowest (2.86 grams) where it was applied in March. The average weight of berries from the unfertilized plots and from those fertilized in February was 3.03 grams.

3. Field plots were selected in the fall of 1931 in Chilton and Cullman Counties, in central and north Alabama, respectively. Nitrogen, 30 pounds per acre, in the form of sulfate of ammonia, was applied at different dates. Each treatment was applied to a matted-row of plants comprising $\frac{1}{100}$ acre. The yield in quarts was recorded for each picking and the average number of berries per quart was determined weekly. The response was similar in the two counties. The results in north Alabama are shown in Table III.

Plants that received nitrogen on September 25, 1931, were blooming heavier than the others in January 1932. This condition prevailed on February 20, but on March 15 plants fertilized on January 18 had produced as many flowers as those fertilized in the fall. All blossoms and fruits were killed by freezing March 6. All flowers producing the crop opened after March 15. On March 15 the fall fertilized plants appeared to need additional nitrogen. On April 15 fall fertilized plants that had received an additional application on February 20, 1932, had the greatest number of berries set, while plants that were treated in January ranked next. All plots receiving nitrogen produced more flowers than the unfertilized plots by April 15. Plants fertilized in September 1931 and again February 1932

TABLE III—INFLUENCE[1] OF NITROGENOUS FERTILIZER[2] APPLIED AT DIFFERENT DATES ON THE YIELD, NUMBER OF FLOWER CLUSTERS, FLOWERS, AND FRUITS OF STRAWBERRIES ON HARTSELLE LOAM IN CULLMAN COUNTY, ALABAMA

Date Nitrogen Applied	Av. Number of Flowers, Clusters, and Fruits						Av. Yield per Plot (Qts.)		Av. No. Berries per Qt.
	Flowers		Flower Clusters		Fruits per Cluster	Fruits on Plants Apr. 15	May 4–14	Total June 1	
	Open Feb. 20	Total Mar. 15	Fruited[3] June 1	Not Fruited June 1					
Sept. 25, '31	428	2,814	102	91	2.8	416	12.3	36.5	153
Jan. 18, '32	192	3,192	94	90	2.6	580	15.8	38.1	171
Feb. 20, '32	216	2,450	86	91	2.8	552	19.8	41.6	158
Mar. 15, '32	228	2,436	73	77	2.2	480	16.1	40.3	155
No nitrogen	220	2,254	77	59	2.3	236	9.3	26.7	164
Sept. 25, '31 Feb. 20, '32	284	3,164	111	82	3.0	840	20.9	51.9	144
Sept. 25, '31	380	3,234	100	80	2.6	332	12.2	34.5	166

[1]The figures are averages obtained from two matted row $\frac{1}{160}$ acre plots.
[2]Nitrogen applied at the rate of 30 pounds per acre from sulfate of ammonia.
[3]Clusters that had ripened one or more fruits.

produced the largest berries and the highest yield. Plants fertilized in January produced comparatively small fruits and leaves. Those fertilized in February made good foliage growth and the leaf growth following the March application was considered to be excessive for best fruit production.

DISCUSSION

In general, applications of nitrogenous fertilizer to strawberries in Alabama in the fall and early winter increased the numbers of flower clusters, flowers, and fruits. Where nitrogen was applied in January or February of the fruiting year to well grown plants, there was usually an increase in the number of open flowers, due to the fertilizer, in about 2 months after treatment. Where the plants were weak at the time of treatment, an increase in the number of flowers was noted earlier, due apparently to the opening of weak buds that would not otherwise have opened. An application of nitrogenous fertilizer to nitrogen-deficient plants, late in the growing season, immediately preceding the harvest period, tended to suppress flower and fruit production at the time, Table II, that leaf growth was most vigorous.

Applications of nitrogenous materials in the fall or early in the fruiting year did not supply sufficient amounts of nitrogen, as indicated by foliage growth and soil nitrate content, over a long enough period to produce large yields. Generally, where nitrogenous fertilizers are applied in the fall, more flowers bloom early and are consequently killed by cold than where the fertilizer is withheld until January or February of the fruiting year. Experimental results show, however, that plants fertilized in the fall and supplied with additional nitrogen later produced a larger crop than otherwise.

From a practical standpoint, it appears that nitrogenous fertilizer should be applied in the fall and again about 90 days prior to the average date of first harvest in order to insure production of a large number of flower clusters that will be effective in producing the crop. A later application may also be advisable to insure the production of berries of large average size.

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Effect of Defoliation on the Fruiting of Concord Grape Shoots

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Abstract

This paper will appear in the bulletin series of the Maryland Agricultural Experiment Station.

REMOVAL of fully expanded leaves, except for a small portion of each leaf blade attached to the petiole, just prior to the opening of blossoms and setting of fruit resulted in a 17 per cent decrease in set of berries, a smaller size of berry, and a 27 per cent decrease in length of shoot growth, even though this early defoliation removed only four or five leaves and new leaf area was rapidly formed. These effects were obtained on individual shoots, only four shoots of each vine being defoliated, compared with adjacent undefoliated shoots of equal length, leaf area, and number of clusters at the time of defoliation. The importance of early development of leaf area also was shown in improvement of size of cluster by cluster thinning before setting of fruit. A cluster thinning practice for Concord grapes to remove blossom clusters from weaker shoots and to limit the number of clusters to a certain number according to the vigor of the vine is suggested.

Effect of Fertilizers on Plant Growth, Yield, and Decay of Strawberries in North Carolina[1]

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THE experiments reported here were carried on at the Coastal Plain Station of the North Carolina Department of Agriculture at Willard, North Carolina. In this section commercial experience has led nearly all the strawberry growers to use large amounts of fertilizers, averaging from 1000 to 1500 pounds per acre. They commonly apply half of this in September or October, and half in December, January, or February.

In these experiments the Missionary was used in 1928 and 1929, and the Blakemore in 1930 and 1931. The fertilizers were applied in split applications in two seasons and in a single one the other two years, as follows: September 28, 1927, and March 1, 1928; January 26, 1929; February 6, 1930; and in September, 1930, and January, 1931. The applications for the 1929 crops were based on an 1800-pound application of a 6 P_2O_5–$3NH_3$–$5K_2O$[2] fertilizer, and for 1930 and 1931 on a 1500-pound application of an 8–4–6 fertilizer. The 1928 test included 20 different treatments of $\frac{1}{20}$ acre each. The 1929 test was on triplicated plots .013 acre in size, but because heavy rains injured some plots not all were used. The 1930 and 1931 plots were in triplicate and $\frac{1}{100}$ acre in size.

The organic nitrogen used in 1928 and 1929 was derived from tankage, and in 1930 and 1931 was from tankage and cottonseed meal, half the nitrogen being derived from each. Hence the fertilizer formula where organic nitrogen was used was approximately—

Year	Fertilizer	Formula
1928	Organic nitrogen	3P+3N
1929	Organic nitrogen	3P+3N
	Organic and inorganic nitrogen	1.5P+3N
1930 and 1931	Organic nitrogen	3.0P+4N+1.0K
	Organic and inorganic nitrogen	1.5P+4N+0.5K

The inorganic nitrogen was derived from nitrate of soda in 1928 and 1929, and half each from nitrate of soda and sulphate of ammonia in 1930 and 1931. The potash was derived from sulphate of potash in 1929 and from muriate of potash in 1930 and 1931.

[1]The cooperation of Charles Dearing, Assistant Director in Charge of the Coastal Plain Branch Station of the North Carolina Department of Agriculture, and of R. A. Lineberry of the Bureau of Chemistry and Soils, is gratefully acknowledged.

[2]Fertilizer formulas in this paper are given in accordance with local usage as follows: P—N—K.

The concentrated fertilizer plot (28–20–20) cannot be compared directly with the other, as it corresponds to a 7–5–5 instead of an 8–4–6 fertilizer.

Except for the inorganic nitrogen plots in 1931, in which many plants were killed by too much fertilizer, increases in yield were obtained from all fertilizer applications. The increases were greatest in 1929 and 1930, when the total yields were least.

The following summary for the years 1929, 1930, and 1931 include the more important results in yields:

TABLE I—AVERAGE YIELD OF STRAWBERRIES IN QUARTS FROM FERTILIZER PLOTS FOR 1929, 1930, AND 1931 AT WILLARD, N. C.

Plot Treatments	Yield in Quarts per Acre				Per cent Increase	No. Plots Averaged
	1929	1930	1931	Av.		
1—No fertilizer	1,615	2,030	6,440	3,362	—	7
2—No N but K, P, or both	2,855	3,017	7,203	4,358	30	21
3—Organic nitrogen	3,577	3,450	8,627	5,058	51	7
4—Inorganic nitrogen	3,046	3,730	6,160	4,312	28	7
5—Inorganic nitrogen and organic N	4,869	4,960	9,690	6,506	94	7
6—N and K, P, or both	3,209	4,045	8,773	5,343	59	23
7—N and K and P and 2 per cent N	—	4,860	9,913	—	74	6
8—28-20-20	—	4,580	8,797	—	58	6

The 1928 results are not given in the table. The plan was somewhat different than for the later years, and where the results apply they are used in the later discussions.

Applied singly or together, potash and superphosphate resulted in increased yields as compared with no fertilizer each year as follows:

	1928	1929	1930	1931	Av. Per Cent
Potash	20	34	57	4	29
Superphosphate	42	67	39	18	42
Both	23	68	50	14	39

Superphosphate was apparently somewhat more effective than potash in increasing yield of fruit.

The increases for the nitrogen over the no-fertilizer plots were as follows:

	1928	1929	1930	1931	Av. of 1929 to 1931 Per Cent
Organic nitrogen plots	40	121	70	34	75
Inorganic nitrogen plots	43	89	84	4	56
Both	—	201	144	50	132

The relative increases for the organic and inorganic N plots were not proportionate for the different years. After the fall application in 1927, and in 1930 and 1931 severe injury occurred in plots receiving inorganic fertilizers alone, the injury being greatest in 1931, when most of the plants died following a strong wind with low humidity on April 29 and 30. It should be noted that the increases from plots receiving both sources of nitrogen were more than from either source alone or the increases from the two separately.

When potash or superphosphate or both were used with the nitrogenous fertilizers (organic and inorganic except in 1928), the yields were greater than when no fertilizer was applied, but were depressed as compared with those from nitrogen only or organic nitrogen plots. The increases were:

	1928	1929	1930	1931	Av. Per cent
Nitrogen+K plots..	98	110	116	41	71
Nitrogen+P plots...	33	118	95	14	65
Nitrogen + K + P plots........	29	83	93	45	63
Nitrogen plots......	42	201	144	50	109

The differences between 71, 65, and 63 per cent are hardly significant but are much less than the 109 per cent increase for the corresponding nitrogen plots. No effect of potash or superphosphate with nitrogen on time of maturity was evident.

For 3 years a concentrated fertilizer was used, in 1929 amophos at a rate to equal the nitrogen in the usual fertilizer and in 1930 and 1931 to equal the nitrogen in two complete fertilizers but with a higher P and K content. The increases were:

Fertilizer	1929	1930	1931	Av. Per Cent
Amophos (16N–20P)...........	126	—	—	—
28–20–20......................	—	126	37	82
N and P.......................	118	—	—	—
Complete	—	139	51	95

The yields in 1929 for the amophos plot were greater than for its corresponding plot, while those for the complete concentrate in 1930 and 1931 were somewhat less than for the corresponding plots.

The complete fertilizer plots, which were given an extra 2 per cent of nitrogen (6 per cent N), gave an increase of 139 per cent in 1930 and 54 per cent in 1931 as compared with the standard complete fertilizer of 93 per cent in 1930 and 45 per cent in 1931. These increases indicate an advantage from a relatively higher per cent of nitrogen in the fertilizer.

When no fertilizer, or potash and superphosphate fertilizers only were applied, the berries were relatively late in maturing. Early berries are usually worth much more than late ones. A single ex-

ample will illustrate this. In 1928, up to May 12 the comparable yields and income (berries at 20 cents per quart) were:

No fertilizer plots—410 quarts	$ 82.00
Superphosphate plots—530 quarts	106.00
Potash plots—645 quarts	129.00
Tankage plots—1100 quarts	220.00
Nitrate of soda plots—1250 quarts	250.00

Thus the nitrogen plots had incomes at the rate of $138.00 and $168.00 per acre more. The use of nitrogen fertilizers is essential to the production of large yields of early berries in this region.

Some records of the relative size of berries from the different fertilizer plots were obtained in 1930. Counts were made at four pickings of 11 to 15 quarts from each plot. The berries from the inorganic nitrogen plots were the largest, averaging 49 per cent larger than those from the "no-nitrogen" plots. In 1931 the largest berries for two pickings (6 quarts per plot per picking) were from the nitrogen and superphosphate plots and averaged 38 per cent larger than berries from the no-nitrogen plots.

In all 4 years the effect of fertilizers on leaf development has been remarkable. Records were taken in 1928, 1929, and 1930, using petiole length and length of middle leaf as indices of vigor. Averages of these lengths in centimeters for some of the plots are:

Plot Treatments	Petiole Length			Length of Middle Leaflet	
	1928	1929	1930	1928	1929
Inorganic nitrogen	24.9	9.5	15.3	9.3	5.8
Complete fertilizer	20.6	15.5	10.9	8.1	7.8
N and P	17.8	13.1	—	7.6	6.5
Organic nitrogen	14.5	12.6	11.8	6.7	6.3
No nitrogen	10.9	8.9	8.4	5.9	5.4

Except for the inorganic nitrogen plots in 1929 and the complete fertilizer plots in 1930, the plots have the same rank in vigor each year, whether petiole length or length of middle leaf is used. Even these measures do not fully indicate the differences between the plots. Thus the inorganic nitrogen plot in 1928 had over twice as many leaves per plant as the no-nitrogen plots, as well as having much larger leaves and longer petioles.

One effect of this dense foliage was to shade the berries, preventing sunlight from drying off the dew and rain, and keeping the leaves and berries damp much longer in the nitrogen than in the no-nitrogen plots. Fungi had a better chance to develop, the berries rotted more, and the berries were paler in color wherever the leaf growth was heaviest. Berries absorb water through the epidermis and the epidermis becomes soft and tender when the berries stay wet long.

In 1928 and 1929 careful pickings were made of all the berries both rotting and sound to obtain measures of the effect of leaf growth on the amount of decay.

Plot Treatments	Per cent Decay of Fruit	
	1928	1929
Inorganic nitrogen	22	13
Complete fertilizer	19	18
N and P	18	20
Organic nitrogen	14	15
No nitrogen	12	9

For 1928 the rank of the plots for decay corresponds with their rank for vigor. In 1929, the rankings also are in general agreement. The most decay on berries in the field occurred in plots with the most vigorous foliage. Observations in the field throughout the United States have confirmed these results. Wherever the growth is rankest, whether due to fertilizer, rich or low lands, wet seasons, weeds or vigor of variety, there the leaves and berries are damp and wet the longest and the decay is greatest. Possibly a rare exception may sometimes occur when severe frosts kill exposed flowers and green fruit on the less vigorous plants and decay spreads from the dead flowers to later ripening fruit.

In 1929, 1930, and 1931, twelve holding tests were made of the berries from the different plots, at ordinary room temperatures. About 20,000 berries were examined in each of 1929 and 1930 and about 50,000 in 1931. The percentage of decay was high because of the length of the holding periods. The following record gives some of the averages:

Plot Treatment	Per cent Decay of Fruit		
	1929	1930	1931
Inorganic nitrogen	34	60	86
Complete fertilizer	53	—	86
N and P	56	71	89
N and K	62	—	79
Organic nitrogen	38	61	80
No nitrogen	23	51	70

The results of these holding tests do not agree closely with the leaf vigor measurements. They are inconsistent and the differences are not great, so that the only conclusion possible is that the berries from no-nitrogen plots have less decay throughout than have the plots receiving nitrogen.

The effect of hot, dry winds on wilting and killing of plants under some treatments in 1930 and 1931 was very marked. In 1930, such weather occurred late in the season and did not injure the crop greatly. In 1931, it occurred early in the season (April 29 and 30) and re-

duced the crop greatly in some plots. In 1930, the injury was greatest to the inorganic nitrogen plots and to the nitrogen plus superphosphate plots. There was slight injury to the plants in the plots receiving complete fertilizers and very slight injury to the no-fertilizer plots, the superphosphate plots, the concentrated fertilizer plots, and the potash plus superphosphate plots.

In 1931, the injury was much worse in the inorganic nitrogen plots where most of the plants were killed. Severe injury also occurred in one of the nitrogen plus superphosphate plots, but it was only slight in the other two. Slight injury also occurred in one of the organic nitrogen plots.

Summarizing the dry weather effects, (1) no injury occurred where both organic and inorganic nitrogen was applied, where potash was applied alone or with nitrogen, and only very slight injury in 1930 where potash was used with superphosphate or in a complete fertilizer, and very slight injury in 1931 in one of the organic nitrogen plots. (2) Severe injury occurred only in plots with a rank leaf growth, being most severe where inorganic nitrogen was applied alone. (3) Severe injury occurred where superphosphate was applied with nitrogen from both organic and inorganic sources, even though none occurred when the nitrogenous fertilizers were applied alone. (4) Injury occurred only under conditions of low humidity and high transpiration rates.

It may be concluded that to prevent serious injury in periods of low humidity a little potash should be included in strawberry fertilizers for conditions such as those in these experiments. Apparently even the amount in the cottonseed meal fraction of the nitrogen fertilizers was sufficient for this purpose if superphosphate was not used. If superphosphate was used some additional potash should be added.

In a paper given in 1931 the necessity of some superphosphate in strawberry fertilizers to insure high flavor was indicated. From the present results, it is apparent that some potash (or impurity carried by muriate of potash) is desirable as well. However, when added to nitrogenous fertilizers either singly or together potash and phosphorus have depressed yields over those obtained when nitrogenous fertilizers were used alone. The inorganic forms of nitrogen are available quickly and except in 1929 forced out a very rank growth. The organic forms, tankage and cottonseed meal, were slower acting and on the average as used were superior. There is in the organic forms some phosphorus, in cottonseed meal a little potassium as well, and in both small amounts of other elements. The small amounts of phosphorus, potassium and other elements may have been sufficient and have been effective when the organic nitrogenous fertilizers were used. The still greater yields when equal parts of the nitrogen were derived from both organic and inorganic sources, and hence the amounts of potassium and phosphorus were relatively and actually still less, may be added evidence that the amounts of these materials needed for strawberries in the soils of the fields used are

small. Because the amount of decay in the fields was correlated with extent of leaf growth and nitrogenous fertilizers increase leaf growth, a balance should be reached between the use of nitrogen to increase yields and the extent of leaf growth that will not unduly increase decay. Fruit buds begin to form in the strawberry by October at Willard, North Carolina. Large plants should be developed by that time which will continue to form fruit buds on through the fall and winter. The plants should have reserves to carry them through the fruiting season, but not such as to form large tops. The problem, to some extent at least then, is concerned with the period during which the nitrogen is available. In the experiments reported here, the organic and inorganic sources of nitrogen together seem most efficient.

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Time of Bud Differentiation in the Dunlap Strawberry[1]

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It is generally conceded that fruit bud formation is associated with an accumulation of carbohydrates. Evidently this accumulation occurs when the carbohydrates synthesized are more than are required for growth and the other activities of the plant. Other things remaining the same, an accumulation of carbohydrates in the growing plant accompanies, or is caused by, a lessening in the amount or percentage of vegetative growth. Among the many factors that may be instrumental in causing such retardation are lack of sufficient moisture at certain times and low temperatures.

The plants that comprised the materials for the studies in 1924 and 1925 were trained to a matted row system and received the usual methods of cultivation for field grown plants. The plants used in 1927 and 1928 were trained in such a fashion as to allow for a fairly detailed record of the history of each individual plant. During these two seasons, 1927 and 1928, the mother plants were allowed to develop only the first five runner series. Each runner series was confined to an unbranched line of runner plants.

The number of plants collected at each date during each of the four seasons was as follows. In 1924, 10 runner series of five plants each; in 1925, three mother plants, each with its unbranched runner series; and in 1928, five mother plants, each with its five unbranched runner series.

Table I, Columns 1 and 2, comprise data which show the percentage* of growth response of the runner plants which were allowed to set. The percentages of increase of all plants during weekly intervals in 1928 are shown in Column 3. It includes all runner plants which were allowed to set and all runner series and runner plants which were pinched off. The average mean weekly temperature and average mean weekly rainfall from April 25 to October 21, during the 4 years of the experiment, are shown in Columns 4, 5, 6, 7 and 8, 9, 10, 11, respectively.

No records were taken in 1924 and 1925 of the time of rooting of

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[1]A part of a thesis submitted to the Graduate Faculty in partial fulfillment of the degree of Doctor of Philosophy.

*The growth response of plants was figured on the percentage which actually rooted in comparison to the number of plants that could have rooted. For example, with the exception of the weeks occurring after the collection of plants from the field, there were 370 possible chances of getting new plants during each week in 1928 and 415 chances during 1927. This was true because the 74 mother plants in 1928 and 83 mother plants in 1927 were limited to five runner series, and each runner plant was allowed to set only the first plant that formed. The number of possibilities of getting new plants each week was a constant factor, while the number of plants that set each week was a variable. Therefore, a setting of 305 plants during the weekly interval of July 9 to 15 is expressed as 82 per cent growth response for that particular period.

TABLE I—Growth Response of Plants to Temperature and Rainfall

Weekly Intervals	Percentage of Runner Plants Set Based on Number of Plants that Could Have Set		Percentage Increase of all Plants During Weekly Intervals 1926	Av. Mean Temperature During Weekly Intervals (Degrees F)				Av. Mean Rainfall During Weekly Intervals (Inches)			
	1927	1928		1927	1928	1924	1925	1927	1928	1924	1925
4/25–4/29	0	—	—	62	49	54	54	0.0	0.0	1.25	.18
4/30–5/6	0	—	—	56	62	61	50	.08	0.75	.08	.13
5/7–5/13	0	—	—	57	61	48	52	1.09	0.0	.24	.13
5/14–5/20	0	—	—	58	65	56	59	2.65	1.16	.58	.40
5/21–5/27	0	—	—	65	67	54	65	1.38	0.0	.85	.06
5/28–6/3	0	0.54	2.00	57	62	60	72	0.15	0.0	0.00	1.57
6/4–6/10	0	.27	1.00	67	63	62	73	0.15	.97	2.64	.52
6/11–6/17	1.68	4.32	75.00	60	68	73	72	0.87	2.62	.74	1.64
6/18–6/24	8.91	26.75	220.00	70	70	73	73	0.16	1.61	2.15	.44
6/25–7/1	15.66	56.48	210.00	76	66	65	68	0.03	1.18	.66	0.00
7/2–7/8	34.21	53.78	180.00	73	79	67	79	0.0	1.25	.12	2.12
7/9–7/15	44.09	82.43	122.00	78	73	70	81	0.01	0.50	0.08	3.03
7/16–7/22	50.12	71.62	89.00	73	77	72	72	0.41	0.48	0.80	0.00
7/23–7/29	52.93	56.76	91.00	74	71	75	71	0.79	1.05	.56	.37
7/30–8/5	38.55	61.62	49.00	68	76	76	68	0.01	1.95	.63	.51
8/6–8/12	52.04	47.83	130.00	70	76	68	70	0.48	0.30	1.54	5.09
8/13–8/19	39.51	77.29	72.00	69	75	65	73	0.89	0.22	.39	.56
8/20–8/26	43.37	53.78	99.00	66	69	75	70	0.0	1.17	1.49	.01
8/27–9/2	50.10	46.75	150.00	72	70	78	75	0.0	2.97	.95	.07
9/3–9/9	41.60	30.00	80.00	77	65	62	78	3.35	0.0	0.00	1.31
9/10–9/16	74.92	43.03	87.00	82	71	57	64	0.60	3.28	1.62	.41
9/17–9/23	29.15	20.32	3.00	59	58	61	69	1.87	0.0	.17	1.35
9/24–9/30	40.67	22.20	14.00	52	50	57	65	3.22	0.0	1.07	1.80
10/1–10/7	43.52	20.32	3.00	55	60	57	53	0.02	0.0	.20	1.84
10/8–10/14	17.64	7.85	.7	51	66	62	46	0.0	0.63	.21	.21
10/15–10/21	4.18	34.28	10.00	51	60	61	41	—	2.32	0.0	.18

the runner plants but during these 2 years the mother plants and the unbranched runner series were selected from a planting that was grown under normal field conditions. The results of these 2 year's study indicated that more accurate information on the growth of the individual plants was advisable for a better interpretation of the data. Although this increased the amount of detailed work, the resulting data have shown that the change was desirable.

In 1927, the mother plants were allowed to develop only five unbranched runner series. Records were kept of the number of runner series and of the number of runner plants removed. No record was kept of time of removal of the plants mentioned above; however, the data in Column 1 is indicative of the growth activity of all plants during weekly intervals in 1927.

In 1928, the plants were trained in a fashion similar to that used in 1927. In addition to the same records that were taken in 1927, complete data were kept of the time of removal of all runner series and of all runner plants.

It will be observed from the data in Column 1 that in 1927 the plants made a slow initial start which was followed by a rapid increase up through the week of July 23 to 29. After this date through September 3 to 9 the further growth response was rather uneven but showed no extreme fluctuations. It should be noted that there was a decline in growth during the week of September 3 to 9 which was followed by a marked increase in growth activity the next week, and this in turn was followed by a decided decrease. From October 8 thru the remainder of the season there was mostly a decline in vegetative growth.

The data in Column 2 show that in 1928 there was a slow initial start followed by a rapid increase in growth through July 9 to 15. After this period the growth response was rather variable showing a much greater degree of fluctuation than it did in 1927. It will be observed that after September 10 to 16 there was lessened activity throughout the remainder of the season and a pronounced decline in growth during the week of September 17 to 23.

The data in Column 3 show that the percentage increase of all plants during 1928 was slow at first followed by a rapid increase reaching the peak during June 25 to July 1. The growth was rather uneven for the weekly intervals up to and including that of September 10 to September 16. There was a decided decrease in growth September 17 to 23. After this date there was a lessened growth activity throughout the remainder of the season.

It will be observed that the total rainfall in 1927 was extremely low as only 9.19 inches fell before September 10. The plants were irrigated three times during 1928. With the exception of water applied on the date of planting, each irrigation during 1928 was followed by a rain within 24 hours. It will be noted that the plants were much more responsive to fluctuations in temperature in 1927 than they were in 1928. This would seem plausible since the soil moisture was a more constant factor in 1927, and the plants would respond more

noticeably to fluctuations in temperature. It will be observed that in 1927, 3 weeks of comparatively dry weather preceded the period before which the first beginning of fruit bud differentiation was noted and also that there was a slight decline in growth during the same period. A greater percentage of buds showed differentiation on September 24, 1927, than on September 10. There was a drop in the average mean temperature from 82 degrees F during September 9 to 16, to 59 degrees F during September 17 to 23 and this was accompanied by a decided decrease in growth response of the plants. The lessened activity during September 3 to 9 probably was caused, in part, by the protracted dry period preceding. The sudden decrease in growth response September 17 to 23, probably was associated with the drop in temperature from 82 to 59 degrees F.

The data in Table I show that during 1928 there was a retardation in growth during September 17 to 23. This probably was caused by the drop in temperature from 71 to 58 degrees F that occurred at the same time, since the heavy rain during the preceding week evidently provided sufficient moisture. Fruit bud differentiation was observed first on September 20 during this year.

The external factors influencing fruit bud formation in 1924 and 1925 were comparable to the factors influencing fruit bud formation in 1927 and in 1928. A drop in the average mean weekly temperature occurred September 3 to 9 in 1924, and remained comparatively low after this date. There was also very little rain from August 16 to September 9, in fact, only one precipitation of 1.49 inches which occurred on August 24. Fruit bud formation was observed first on September 7, and evidently the chief external factors accompanying this period were low temperature and lack of moisture. No growth data were taken, but evidently vigor of growth was slackened in the same manner as that of 1927 and of 1928. In 1925 only 0.64 inches of rain fell from August 13 to September 2. This dry period evidently was influential in causing the proper nutritive condition to take place in the plants, because fruit bud formation was observed first on September 2. There was a drop in the average mean weekly temperature September 10 to 16 and the temperature was comparatively low for the remainder of the season. Low temperature was not a factor in causing the initiation of fruit buds on September 2. Low temperature in its influence in retarding vegetative growth was evidently influential in causing buds to differentiate after September 2.

A summary of the data shows that in 1924 fruit-bud formation was preceded by low temperature and lack of moisture; in 1925, by lack of moisture; in 1927, by lack of moisture; and in 1928, by low temperature.

These data agree with those of other investigators. Kirby (3) who worked with the apple in Iowa, Abbott (1) who worked with the tung oil tree in Florida, and Wiggans (5) who worked with pears in California, all reported that lack of soil moisture was associated with the time of fruit-bud formation. Goff (2) and Morrow (4) worked with the strawberry in Wisconsin and Iowa, respectively.

They maintained that low temperature was the chief external factor associated with the time of fruit-bud formation.

The data presented in this paper show that the external factors of low temperature or lack of moisture taken separately or in combination are accompanied by a decrease in vegetative growth and are associated with the time of fruit-bud formation.

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The Interrelation of Firmness, Dry Weight, and Respiration in Strawberries

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Considerable work has been done in recent years on the firmness or handling quality of strawberries in relation to growing conditions and to correlate the firmness with the composition or metabolism of the berries. Ripe strawberries have a relatively low (7.0 to 12.0 per cent) but rather variable amount of dry matter. It seems reasonable to suppose that the amount of solids, particularly in the insoluble solids that form the structure of the berries, would be largely responsible for the firmness of the fruit and that a relatively high moisture content would tend to dilute these solids and result in soft berries. Similarly a high moisture content might tend to dilute the materials controlling the rate of respiration and thus lower the respiratory intensity. This paper, based on the results of one season's work presents a comparison of the dry weight, firmness and respiration of a number of strawberry varieties.

Fig. 1. Modified Idaho fruit pressure tester as designed by E. A. Gorman of the U. S. Department of Agriculture.

Material and Methods

The strawberries for this work were obtained from the breeding plots of G. M. Darrow and G. F. Waldo at Glenn Dale, Maryland. The berries were picked in the morning and taken immediately to the cold storage laboratory on the Arlington Experiment Farm near Washington, D. C., where they were sorted and sampled for dry weight, and 500 gram lots weighed out and placed at 60 degrees F for determination of respiratory rates. Dry weight was determined by drying 50 gram samples at 70 degrees C with vacuum to constant weight. The firmness of the berries was determined at 60 degrees

TABLE I—FIRMNESS, DRY WEIGHT AND RESPIRATION OF STRAWBERRY VARIETIES. PICKED JUNE 6, 1932

Variety or U.S.D.A. Seedling Number	Firmness (Gms)	Dry Weight	Respiration at 60 Degrees F						
			Mg CO_2 per		Mg CO_2 per 100 Gms		Cc O_2 per		$\frac{CO_2}{O_2}$ Ratio
			Kg.	Hr.	Dry Wt.	per Hr.	Kg.	Hr.	
Redheart (632)	982±5.6	10.10	90.1		89.2		39.0		1.17
No. 911	965±6.4	12.20	88.4		72.5		37.8		1.19
Average of firm varieties	974	11.15		89.3		80.1		38.4	1.18
No. 904	852±8.1	8.35	87.0		104.2		40.3		1.10
Aroma	817±8.3	10.15	100.3		98.8		41.8		1.22
Portia	802±6.5	10.45	72.2		69.1		32.6		1.13
Average of medium firm varieties	824	9.65		86.5		89.6		38.2	1.15
Wm. Belt	791±8.0	11.05	89.5		81.0		36.6		1.25
Gassett	788±4.8	8.35	64.2		76.9		27.0		1.22
Southland	786±5.9	9.80	78.1		79.7		32.6		1.22
Variety from Thomas	752±5.9	7.75	57.3		73.9		25.0		1.17
Average of soft varieties	779	9.24		72.3		78.2		30.3	1.22

TABLE II.—FIRMNESS, DRY WEIGHT AND RESPIRATION OF STRAWBERRY VARIETIES. PICKED JUNE 8, 1932.

Variety or U.S.D.A. Seedling Number	Firmness (Gms)	Dry Weight	Respiration at 60 Degrees F: Mg CO_2 per Kg	Mg CO_2 per Hr.	Mg CO_2 per 100 Gms Dry Wt.	Mg CO_2 per 100 Gms per Hr.	Cc O_2 per Kg.	Cc O_2 per Hr.	$\frac{CO_2}{O_2}$ Ratio	
Redheart (632)	949±5.3	10.8	100.3		92.8		45.8		1.12	
Fairfax (613)	913±9.5	11.5	93.1		80.9		39.7		1.20	
Average of firm varieties	931	11.15		96.7		86.9		42.8		1.16
Dorsett (633)	847±7.5	12.0	91.4		76.2		40.7		1.14	
Missionery	846±6.7	11.4	88.8		77.9		37.9		1.19	
Average of medium firm varieties	847	11.7		90.1		77.1		39.3		1.17
Howard 17 (Premier)	781±5.9	10.5	95.6		91.0		43.0		1.13	
Southland	776±6.7	9.9	80.1		80.9		35.0		1:17	
Gassett	773±7.4	8.8	65.7		74.7		28.1		1.19	
Average of soft varieties	777	9.7		80.5		82.2		35.4		1.16
Variety from Thomas	767±8.4	7.9	57.4		72.7		—		—	
No. 652	766±5.3	7.9	56.8		71.9		24.0		1.20	
Big Late	761±4.4	8.1	64.6		79.8		25.1		1.31	
Average of very soft varieties	765	8.0		59.6		74.8		24.5		1.25

F with a modification of the pressure tester[1] or squeeze tester of the type described by Verner (8). The pressure tester used is illustrated in Fig. 1. A 2,000-gram scale was used and the plunger disc moved through a distance of ⅞ of an inch. The rate of respiration was determined at 60 degrees F during three periods of 12 hours each by the method described by Haller and Rose (3). Full ripe berries of approximately the same stage of maturity were used in all cases.

Results

The strawberries were picked at three different times and the results from the second and third picking are presented in Tables I and II. The results from the first picking were similar to those for the second and third but are not presented here as the dry weights were not considered entirely reliable due to charring of most of the samples.

Although not entirely consistent the results show a direct correlation between dry weight and firmness. A coefficient of correlation of $+ .619 \pm .10$ was obtained by combining the results of the two pickings. This is in agreement with the results of Kimbrough (4) who found that strawberries from irrigated plots were much softer and had a much lower dry weight than those from non-irrigated plots. It also agrees with the observation of Darrow (2) that small berries of a variety were firmer and had a higher dry weight than large berries. Cochran and Webster (1) reported no appreciable influence of fertilizers on firmness or dry weight of berries under field conditions. On the other hand nitrogen fertilizers are reported by Shoemaker and Greve (7) to result in softer berries with no significant change in dry weight as compared with fruit from check plots.

That the respiratory rate based on the fresh weight (mg CO_2 per kg hr) was directly correlated with the dry weight ($r = + .779 \pm 0.06$) is apparent from Tables I and II. Thus the respiratory rate appears to be not so much a measure of the metabolic activity of the different varieties of strawberries as due to differences in the amount of respirable material. The rate of respiration was computed on a dry weight basis and is shown in the tables as mg CO_2 per 100 grams dry weight per hour. This would probably be a more accurate index of metabolic activity, and on this basis there was no longer any significant correlation between the respiratory rate and dry weight.

The respiratory ratio (cc CO_2 : cc O_2) was not correlated with dry weight or firmness in the different varieties. Overholser, Hardy, and Locklin (5) from their results conclude that the firm-fleshed varieties had a lower respiratory ratio than the soft-fleshed sorts. According to their data, however, the average difference in respiratory ratio between the firm-fleshed and soft-fleshed varieties was only 2.5 to 4.1 per cent which hardly seems significant especially since with the mature berries the two firmest varieties had a slightly higher ratio than the two softest varieties.

[1]Acknowledgment is due to E. A. Gorman for designing and constructing the pressure tester used.

The firmness of the different varieties from Glenn Dale, Maryland, was also directly correlated ($r = + .667 \pm 0.09$) with their respiratory rates (mg CO_2 per kg hr) as shown in Tables I and II. This probably should not be interpreted as meaning that firmness was directly associated with respiratory rates, but rather that both are influenced in the same manner by differences in dry weights. Overholser, Hardy, and Locklin (5) conclude that with the strawberry varieties tested greater firmness of flesh was not directly correlated with low respiratory intensity. Their results, however, indicate an indirect correlation between firmness and low respiration intensity which is in conformity with the results presented in Tables I and II. With strawberries from fertilizer plots, however, Overholser and Claypool (6) found that nitrogen decreased firmness and increased respiratory intensity. Apparently increased nitrogen may increase the metabolic activity of a given amount of dry matter so that the relation between firmness and respiratory intensity is reversed.

Summary

A study was made of the dry weight, firmness, and respiration of different varieties of strawberries grown under similar conditions and picked at the same stage of maturity. A direct correlation was found to exist between the dry weight and the firmness of the different varieties. The dry weight was also found to be directly correlated with the respiratory rate when figured on a fresh weight basis. A direct correlation also existed between firmness and respiratory rate computed on a fresh weight basis. The rate of respiration computed on a dry weight basis is considered a more reliable index of metabolic activity. On this basis there was no apparent relation between respiratory rate and firmness or between respiratory rate and dry weight. There was no apparent relation between firmness and the respiratory ratio of the different varieties.

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The Lateral Movement of Elaborated Foods in the Grape Vine

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PRACTICAL application of methods of flower cluster and cluster thinning grapes (1)(2) has been retarded by lack of positive information on the lateral movement of elaborated food materials in the vine. Many growers believe that shoots without fruit contribute very little or nothing to fruit on other shoots.

Earlier work (3) showing that an average cluster of table grapes requires the product of at least 16 leaves indicated that the fruit must use foods synthesized at some distance. This means a movement of the food materials for 25 inches or more along the shoot carrying the fruit, but gives no indication of what movement between shoots or vine parts may occur. To secure data on this latter movement as well as between vine parts, several series of defoliation and thinning tests were carried out. The details of these tests and the parts of the vines utilized are enumerated below.

A. *Spurs bearing two shoots.* In one series the upper (apical) shoot was defoliated* but the fruit retained while on the lower (second) shoot the leaves were retained and the fruit removed. In a second series the treatment of the two shoots was reversed.

B. *Branched Arms.* Arms which branched in 3- or 4-year old wood were selected. They were pruned so that each branch terminated in one spur. On the Muscat, the spurs were left 3 or 4 inches long with two or three buds each. The Malaga was pruned half-long with spurs 10 to 14 inches long. Only the two upper shoots on the Malaga spurs were permitted to develop. In this series the shoots of one spur of the branched arm were defoliated and the fruit retained, while the fruit on the shoots of the other spur was removed.

C. *Defoliated Arms.* Shoots on arms arising from large branches near the crown of the vine were defoliated, while the fruit was retained. The leaves and fruit on the shoots of the other arms of the vine were not disturbed.

D. *Canes.* Only the two highest shoots on fruit canes were permitted to develop. The fruit on these shoots were retained, while the leaves, except one, were removed. All canes used were 2.5 feet or more long.

E. *Thinning.* Individual arms of vines were thinned so that the ratio of clusters to shoots was 1 to 1, while on other arms of the same vine the number of clusters was reduced so that the ratio was 1 cluster to 2 shoots. Unthinned arms on the same vines served as the check. In other lots the entire vines were thinned to these ratios.

*Defoliation, as used in this paper, refers to the removal of all but one leaf. The one leaf was retained to prevent the withering of the shoot and its fruit.

In addition to the defoliation series outlined above, several of the series were duplicated and the members ringed (girdled) below the union of the part carrying the fruit with that carrying the leaves. It was hoped that this operation would isolate these parts of the vines.

In all tests, only shoots and clusters of average size were utilized. The cluster was reduced by berry thinning when it was found to be above average size. Shoots bearing undersized clusters were not used.

Development and maturity of the fruit were used as indication of the lateral movement of the synthesized foods in the several tests. To measure these, degree Balling of the expressed juice, acidity, and average weight of berry were determined. These measurements are shown in Table I.

TABLE I—THE MOVEMENT OF ELABORATED FOODS IN THE GRAPE VINE AS INDICATED BY THE DEVELOPMENT AND MATURITY OF THE FRUIT ON DEFOLIATED AND THINNED VINE PARTS

Variety	Year	Treatment	Degrees Balling of Expressed Juice	Acidity, Gms Tartaric per 100 Cc	Av. Weight of Berry (Gms)
		Series A			
Muscat ...	1930	Spurs—upper shoot with fruit	23.8±.375	0.59±.023	3.6±.220
		Spurs—second shoot with fruit	21.6±.403	0.54±.007	3.8±.172
		Spurs—check on the same vines........	22.7±.614	0.59±.021	3.7±.137
Tokay.....	1930	Spurs—upper shoot with fruit	13.2±.415	0.87±.008	3.3±.199
		Spurs—second shoot with fruit	14.3±.631	0.80±.009	3.9±.170
		Spurs—check on the same vines	13.3±.160	0.90±.005	3.3±.295
		Series B			
Muscat....	1930	Branched arms—ringed (girdled)	23.1±.706	0.66±.038	3.6±.127
		unringed (not girdled)	16.6±.349	0.75±.025	3.2±.031
		check on the same vines	16.3±.321	0.77±.009	3.0 ±.126
	1931	Branched arms—ringed	28.3±.230	0.55±.005	4.9 ±.115
		unringed	24.3±.180	0.54±.006	4.8 ±.129
		check on the same vines	22.5±.190	0.54±.007	5.1 ±.126
Malaga....	1931	Branched arms—ringed	21.9±.220	0.54±.003	4.8 ±.176
		unringed	19.2±.251	0.65±.009	4.4 ±.030
		check on the same vines	18.4±.211	0.66±.011	4.4 ±.101

TABLE I—*Continued*

		Series C			
Tokay	1930	Defoliated arms	13.3±.350	0.70±.004	3.3 ±.182
		Check on the same vines	13.0±.314	0.77±.005	3.2 ±.121
		Series D			
Muscat . .	1931	Canes—fruit on shoots at apical end	22.4±.250	0.52±.007	4.8 ±.129
		Canes—check on the same vines	22.6±.245	0.54±.011	4.7 ±.118
Thompson Seedless	1932	Canes—fruit on shoots at apical end	17.8±.262	0.85±.022	1.08±.015
		Canes—check on the same vines	18.3±.293	0.81±.018	1.28±.016
		Series E			
Muscat	1932	Arms—thinned to 1 cluster to 1 shoot	20.1±.369	0.59±.012	3.3 ±.060
		Arms—thinned to 1 cluster to 2 shoots	21.3±.371	0.58±.023	3.0 ±.078
		Check—about 2 clusters to 1 shoot	20.8±.283	0.57±.003	3.1 ±.021
		Entire vines thinned to 1 cluster to 1 shoot	23.4±.293	0.56±.002	3.7 ±.032
		Entire vines thinned to 1 cluster to 2 shoots	25.4±.213	0.57±.006	3.7 ±.046

Although it seemed advisable to present the data for each series in Table I, it seems unnecessary to discuss them individually. Briefly stated, the fruit of the defoliated shoots was as well nourished, as indicated by degree Balling (total solids), acidity, and weight of berry, as that of the check shoots. This was equally true of immature and of well matured fruit.

The A Series shows that the synthesized foods may move from one shoot down into the spur and then up through another shoot of the spur to the fruit. The direction of movement had little or no influence; i.e., the fruit on upper shoots which were defoliated developed as well as that on the second and lower shoots. In the first case there were no leaves beyond the fruit, while in the latter case the upper shoots retained their leaves.

In Series B a still longer and more devious movement of foods is indicated. Here they were translocated downward from the shoots with leaves to the spur and down that branch of the arm into 3- or 4-year old wood to the base of the branch carrying the defoliated shoots with the fruit, whence it moved upward through similar vine parts to the fruit. In the Muscat the total distance through which the food moved was about 18 inches. In the Malaga, owing to the half-long cane pruning, it was about 3 feet.

The C Series demonstrates the movement of elaborated foods from the leaves down to the large branches of the head of the vine and from there up through another arm to the fruit on the defoliated shoots of that arm. The distance of movement of the food materials

in this case was not so great as in the Malaga branched arms, but in this case the material had to move along vine parts which were over six years of age.

The results of Series D indicate that food materials may travel considerable distances upward from the leaves. In these tests the defoliated shoots with the fruit were at the apical end of the fruit canes, while the shoots with leaves were at the base—usually on older wood or on another spur. The distance of the movement was in every case more than 2.5 feet.

Objection may be made to the results presented so far, that the movement of materials occurred only as a result of the severe defoliation. This objection seems to be fully met by the data for the differential thinning tests. In this the vines were under normal vineyard conditions. Since thinning of the crop is not injurious the vines, doubtless, functioned normally. In these tests, if synthesized foods did not move, it might logically be supposed that this failure would be reflected in earlier maturing of the fruit, as when entire vines were thinned to the same degree. Actually all the fruit on these vines matured uniformly. In other words, the synthesized foods must move readily among the different parts of the vine so that, within limits, they are equally available to any cluster regardless of its position.

Ringing resulted in a higher percentage of total solids in every case. This was due to the restriction of the passage of elaborated foods as long as the wounds were open, making practically all of the product of the leaves above the ring available for the development and maturing of the fruit on that part of the vine. This condition is somewhat analogous to that where the crop of the entire vine was thinned. In the check and unringed lots, where a considerable quantity of the synthesized foods went to other parts of the vine, a smaller quantity was available for the nutrition of the fruit on these parts.

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Effects of Fumigation of Different Varieties of Vinifera Grapes With Sulphur Dioxide Gas

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SULPHUR dioxide has been used in California for many years in fumigating loaded cars of grapes to retard mold growth during shipment to market. It is estimated that 30 to 50 per cent of the shipments from California in recent years has been treated with sulphur dioxide. Translated into carloads, in a normal year of 60,000 carlot shipments, 18,000 to 30,000 carloads would receive treatment. Investigations have been conducted the past 3 years at Fresno, California, by the United States Department of Agriculture on the treatment of grapes with sulphur dioxide and that phase of the work pertaining to the rate of absorption of SO_2 by different varieties of grapes and the amount injurious to them is reported herein.

Methods

In these investigations the fruit was treated in lugs, the usual shipping container, and was exposed in most cases to gas concentration between 1½ and 2 per cent SO_2 by volume in a tight gassing chamber. This concentration of SO_2 is commonly used in treating cars of grapes. Lugs were removed from the chamber at various time intervals and grapes were taken from various parts of the lugs for analysis. These samples were immediately crushed through a coarse food chopper and held in completely filled glass stoppered bottles until they could be analyzed, which was usually within several hours. The volumetric iodine method of SO_2 analysis (2) was used. It was found to be satisfactory when thiosulphate traps were used to catch any iodine that might escape from the receiving flasks, and the water bath for the receiving flasks was cooled to about 10 to

TABLE I—Showing the Possible Error Due to the Influence of the Temperature of the Water Bath on the Loss of Iodine in the Determination of the SO_2 Content of Fumigated Grapes

	Temperature of Water Bath (Degrees C)		
	33–35	25–28	10
N/20 I_2 in flask at start	39.28 cc	39.28 cc	39.28 cc
I_2 in flask at end	38.75	38.92	39.25
N/20 I_2 lost	.53	.36	.03
Mg. of SO_2 equivalent	.9	.6	.05
P.p.m. if 200 g. sample used	4.5	3.0	.25

15 degrees C. Table I shows the error that may be introduced by loss of iodine at higher temperatures. Precautions were taken throughout the preparation of the sample and the analysis to prevent loss of SO_2 and to exclude oxygen from the sample bottles and distilling

flasks. The method was found to give 75 to 90 per cent recovery of SO_2 from grapes and about 98 per cent recovery from water to which known quantities of standard H_2SO_3 solution had been added. No doubt there is some oxidation and combination of SO_2 in grape tissue thereby preventing better recovery from grapes.

In all the experiments untreated grapes from the same lot were analyzed and the amount of SO_2 recovered from the treated grapes above the value for the untreated fruit, was considered the amount absorbed during the treatment. The untreated grapes always had a small "SO_2 value," varying from about 5 to 10 p.p.m.

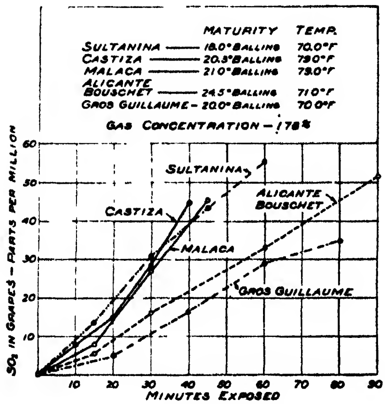

FIG. 1. Diagram showing rate of absorption of SO_2 by different varieties of grapes. Sept. 1932.

RESULTS

Rate of absorption: Figs. 1 and 2 give the absorption rate of SO_2 for different varieties of grapes. The conditions of fruit temperature, fruit maturity, gas concentration, and length of exposure to the gas are shown. These factors have been discussed by Jacob (3) and Winkler (4) in their work on the utilization of sulphur dioxide in marketing grapes. It is apparent from Figs. 1 and 2 that in addition to the above factors, varietal characteristics exert an influence on the rate of absorption. In both experiments Gros Guillaume (Ribier) has shown the lowest absorption rate in spite of being slightly immature in one case as indicated by the Balling test in Fig. 2. The factor of immaturity usually increases the absorption rate as do higher temperature and higher gas concentration. In 1931 Gros Guillaume also exhibited a low absorption rate as shown in Table II. Emperor and Alicante Bous-

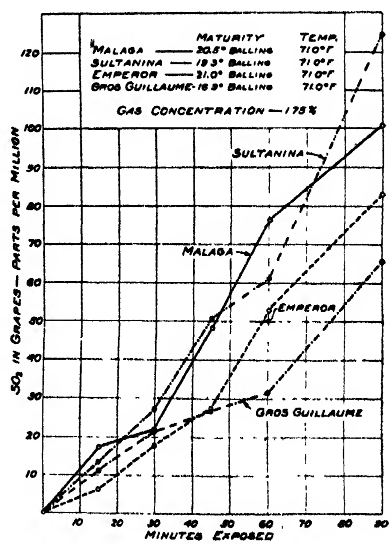

FIG. 2. Diagram showing rate of absorption of SO_2 by different varieties of grapes. Oct. 1932.

chet likewise take up SO_2 at lower rates than do Sultanina (Thompson Seedless), Malaga and Castiza (Red Malaga) as indicated in Figs. 1 and 2. Table II shows that in 60 minutes exposure to SO_2 gas of about the same concentration, Gros Guillaume, Alicante Bouschet, and Emperor absorbed less than Sultanina, Malaga, and Castiza except in one experiment with Sultanina when the average gas concentration used was only 0.6 per cent and in an experiment with Emperor in which an average gas concentration of as high as 2.91 per cent was used. At shorter exposures, the differences are not so marked but are similar.

Although varieties may be roughly classified according to their SO_2 absorption rate we have noted wide variation within the variety. In our experiments with Sultanina, absorption rates in 1930 were much higher than observed in 1931 and 1932. This is probably accounted for not by the maturity or temperature of the fruit but by the fact that the grapes used in the first season were from ungirdled vines and were smaller and less firm than the fruit from girdled vines used the last two seasons. These differences existing within the variety are recognized by some agencies doing commercial fumigation who find it necessary to modify their methods of application according to the type of fruit being treated.

Tolerance of grape varieties to SO_2 gas: The inspection of the grapes for sulphur dioxide injury was usually made after holding the fruit at 40 to 45 degrees F, for about 10 to 12 days, which is approximately the time required for shipment to eastern markets in refrigerator cars. Inspection included an examination of the stems, capstems and berries for changes in color, or physical condition, and for change in taste of fruit. Comparisons were always made with untreated grapes from the same lot of fruit held under the same conditions of temperature.

The first injury from sulphur dioxide usually appears as yellowing of the capstems and stems. This is not objectionable, for the customary browning of the stems and capstems accompanying drying is prevented to a great extent. In some varieties with intensely green stems, notably Gros Guillaume, the green color is not bleached to yellow but is retained even after the stems have dried. In Table II stem and capstem injury as described above, and slight injury to berries is denoted by sub-numeral "1." This injury is not serious enough to affect the sale of the grapes.

More serious injury develops upon longer exposure to sulphur dioxide gas, the severity of the injury usually being proportional to the amount of sulphur dioxide absorbed by the grape tissue. On colored varieties, especially red grapes such as Emperor and Castiza, bleaching of the red color takes place, usually starting at the capstem attachment and progressing toward the other end of the berry. The general effect, in addition to bleaching is to give the grapes a lifeless, dull appearance. Blue varieties such as Gros Guillaume and Alicante Bouschet are usually difficult to bleach and the change in color is from blue to reddish blue. In white varieties such as Sultanina and

TABLE II—AMOUNT OF SO_2 ABSORBED BY, AND INJURIES OBSERVED TO VINIFERA GRAPES EXPOSED TO SO_2 GAS FOR DIFFERENT PERIODS OF TIME

Variety	Date	Balling Test of Juice	Fruit Temp. (Degrees F)	Ave. Conc. Gas (Per cent)	Parts Per Million Absorbed in Minutes Exposed									
					5	10	15	20	30	45	60	80	90	120
Sultanina (Thompson Seedless)	8/28/30	23.1	75	1.1	19	52_2	51_2	76_3	84_3	169_3	229_3			
	8/29/30	23.1	72	2.0	25		53_2	62_2	92_3	119_3	262_3			
	9/11/30	—	68	1.4	14	18	46_2	74_2	99_3	150_3				
	8/3/31	22.1	81	1.1	7	18	30_2	33_2	55_2	79_3	107_3			
	8/14/31	21.0	77	.6	6	10_1	17_1	14_1	27_2	37_2	45			
	9/28/32	18.0	70	1.6			14_1		31_1	43_2	56_3			
	10/13/32	19.3	70	1.7			13_1		27_2	52_2	61_2		127_3	
Malaga	8/5/31	18.0	82	1.3	7	17		26_2		92_3				
	9/2/31	—	78	1.2	2	7	4	17	18_2	32_3	64_3	78_3	117_3	
	9/20/32	21.0	79	2.1			9		28_2	45_3		109_3		180_3
	10/13/32	20.5	70	1.7			17		22_2	48_2	77_3		101_3	
Castiza (Red Malaga)	8/18/31	19.2	72	1.7	4		4		22_2		67_3		115_3	
	9/20/32	20.3	79	2.1		7_1		17	28_2	44_3		209_3		
Gros Guillaume (Ribier)	8/18/31	19.3	72	1.7	4		8		18_1		41_1		57_1	
	9/9/31	—	74	1.7	2	5		12	13		26_1		61_1	
	9/28/32	20.0	70	1.6				5		16_1	29_1	35_1		
	10/13/32	16.9	70	1.7			6		18	27_1	31_1		65_2	
Emperor	11/21/30	21.0	52	1.7	2	6		13	10	14_2	31_2		43_2	
	11/24/30	21.0	74	2.9			16		32	83_2			158_3	209_3
	10/13/32	21.0	70	1.7			11_1		21_2	28_2	53_3		83_3	
Muscat of Alexandria	9/23/32	24.1	71	1.9		1			13	17_1	26_2	57_3		
Alicante Bouschet	9/17/31	20.8	69	1.3	2	6		17	15	33	41		55_2	
	9/23/32	24.5	71	1.9			6		18	17	33_2		52_2	75_3
Zinfandel	9/18/31	24.2	71	2.2	3	6		18	21	33	49_2		76_3	
	9/22/32	24.0	86	1.8			18		40	75_2	91_3		200_3	269_3

Footnote—Sub-numeral 1 refers to slight non-commercial injury usually bleaching of stems and capstems.
Sub-numeral 2 refers to commercial injury usually changes in color and flavor of grapes.
Sub-numeral 3 refers to severe injury characterized by very bad flavors and color changes.

Malaga, the change in color is that of yellowing and dulling to an "ashy" pale yellow color. Upon exposure to room temperatures, in a day or two browning of the fruit usually takes place. In many cases, fruit which was not considered commercially damaged when inspected immediately after removal from 40 to 45 degrees F developed enough brown color and off-taste in one day's exposure to temperatures of 70 to 80 degrees to make the fruit unsalable. With severe sulphur dioxide damage, browning may take place even at cold storage temperatures.

These injuries to the appearance of the grape are often accompanied by objectionable changes in their taste. Immediately after treatment, the grapes may have a sulphurous taste even without showing injury to the color, but upon being held at car temperature for 10 days this taste disappears except in badly injured lots. Usually a "cooked" taste remains in grapes showing noticeable color changes and either one of these injuries would be sufficient to make the grapes unsalable. Such injury, when severe enough to be readily noticeable and spoil the salability of the grapes, has been designated by sub-numeral "2" in Table II.

Very serious injury, shown in Table II, by sub-numeral "3," is characterized by almost total bleaching or browning, softening of the grapes, sinking at the capstems and very offensive "cooked" or sulphurous flavors.

There is considerable variation in the amounts of sulphur dioxide found to be injurious not only to different varieties but also to different lots of grapes within the variety. In Sultanina grapes, commercial injury was noticed in fruit containing 30 to 53 p.p.m. of SO_2 in the tissue. Malaga grapes absorbing 18 to 28 p.p.m. showed injury when inspected (as indicated in the above experiments). In the case of Castiza, 22 and 28 p.p.m. injured the grapes by permanently bleaching some of the color. Gros Guillaume grapes withstood considerable concentrations of sulphur dioxide, even 61 p.p.m. not injuring them, but in another experiment 65 p.p.m. did injure the color and flavor. With Emperor grapes 14 and 21 p.p.m. injured the fruit in two experiments, but in another the fruit withstood 31 p.p.m. Alicante Bouschet grapes were injured by 32 and 55 p.p.m. and Zinfandel was injured by 40 and 75 p.p.m. in the tissue of the grape. As a general statement, in only one case, excepting Ribier, did any lot of grapes absorb more than 55 p.p.m. of SO_2 in the tissue without showing commercial injury. These results are not in exact accord with those of Jacob (3) and Winkler (4) who reported 50 to 100 p.p.m. in the grapes as the correct concentration to use, but recommended keeping in the lower part of the range. Our results indicate that about 20 p.p.m. in the grape tissue is a safer amount for grapes grown in the San Joaquin Valley although some varieties such as Ribier and some lots may withstand more than this as indicated in Table II. Shipping tests (1) with inoculated grapes have shown that small amounts of SO_2 in the grapes when shipped are of value in retarding mold

growth, only 6 p.p.m. in one test holding the number of moldy berries to one-half of those in the untreated lot.

These investigations pertaining to the behavior of different varieties of grapes to treatment with SO_2 gas are being continued, as are studies relating to the effectiveness of SO_2 in the control of the mold, the effect on the physiological activity of the fruit and the actual application of the gas to problems in mold control in cold storage as well as in transportation of grapes.

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Studies on the Removal of Arsenical Spray Residue from Grapes[1]

By J. M. Lutz and G. A. Runner, *U. S. Department of Agriculture, Washington, D. C.*

CONTROL of the grape berry moth (*Polychrosis viteana* Clem) in certain sections of the United States is usually accomplished by spraying with lead arsenate. Owing to the relatively small size of grape berries and the consequent large amount of surface per pound of fruit, the amount of arsenical residue found on grapes may be considerably above the tolerance. Lead arsenate carried on the stems is also a factor in this respect. Grapes may carry as much as five times the arsenical tolerance when sprayed only twice, the last application being applied shortly after blossoming, three months before harvesting. A third arsenical application a month after blossoming may result in an arsenical load of ten times the tolerance.

There are still many unsolved problems pertaining to the removal of arsenical spray residue from grapes and this paper should therefore be considered as a progress report and not as the final word on this subject. The experimental work reported herein was performed in northern Ohio in 1930 and 1931, in southwestern Michigan in 1931, and at Arlington Farm, Virginia, in 1932. During the course of the work the following varieties of grapes were used, namely, Concord, Catawba, Delaware, Niagara, Moore Early, Worden, Ives, and Clinton.

Figures on the hydrochloric acid concentration given in this paper are based on the percentage of actual acid and must be multiplied by 3 to secure the number of parts of commercial hydrochloric acid per 100 parts of water.

Results

Efficiency of solvents: The efficiency of various solvents in the removal of arsenical spray residue is shown in Table I. The grapes were washed by submerging them for 5 minutes in the solvent and then submerging them for 5 minutes in rinse water. The temperature of the solutions was 66 degrees F. Because of the inefficiency of the materials other than hydrochloric acid, most of the work was conducted with the latter material only.

Spraying with hydrochloric acid before harvesting: The possibility of removing arsenical spray residue by spraying the grapes on the vines with 0.33 per cent hydrochloric acid followed by a similar spray of water for rinsing was investigated. Although this method produced a marked reduction in the visible residue on the outside of the clus-

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ters, only from 4 to 50 per cent of the total As_2O_3 present on the grapes was removed. A somewhat higher percentage of the arsenical residue was removed from grapes which had been sprayed with calcium arsenate than from those sprayed with lead arsenate. Because of the inefficiency of this method and the detrimental effect of acid on spraying machinery, this method is impractical. Spraying with water alone was found to be almost completely ineffective.

TABLE I—EFFECT OF VARIOUS SOLVENTS ON ARSENICAL RESIDUE REMOVAL FROM GRAPES

Solvent	Per cent As_2O_3 Removed
0.4 per cent hydrochloric acid	86
2 per cent sodium carbonate	55
2 per cent trisodium phosphate	43
2½ per cent acetic acid	31
1 per cent ferric chloride	23
Water	0

Effect of spreader upon removal of residue: The type of spreader or sticker used in the spray application was found to have little or no effect on the ease of removal of the arsenical residue. (Table II.) The fruit was washed by dipping in the hydrochloric acid solution for five minutes followed by a 5-minute submergence in rinse water. Calcium arsenate spray was somewhat easier to remove than lead arsenate spray.

Effect of exposure and strength of acid: The relationships of acid concentration and length of exposure to arsenical residue removal were found to be similar with grapes to those which have been reported for apples. For dipping, at least 4 to 5 minutes is required to obtain satisfactory results with grapes. Exposure of over 10 minutes can not be recommended because of danger of injury to the fruit. Increasing the acid concentration was found to increase the efficiency of arsenical residue removal but not in proportion to the increase in concentration. Acid concentrations greater than 1 to 1.3 per cent of actual acid should not be used because greater concentrations than this do not result in much greater efficiency and there is danger of injurious effects to the fruit. Rather than increase the acid strength beyond this point, it would be preferable to increase the efficiency of the acid solution by other methods such as agitation, applying the acid in the form of a spray, or raising the temperature of the acid solution as recommended for apples.

Washing grapes for juice purposes: The washing of grapes in juice plants can be accomplished with only slight modifications of present practices. In some instances, grapes are now being washed in water with equipment which could easily be modified for washing grapes in acid and, of course, rinsing with water. Where no equipment for washing is available, a machine could be built at relatively low cost. This machine could consist of an endless conveyor carrying the grapes first through a tank containing an acid wash and then

through a water rinse either in a tank or in the form of a spray. A better method would be to apply both the acid wash and the rinse water as sprays. Grapes can also be washed in commercial apple washing machines of the conveyor type, by carrying them through the machine in shallow trays. Washing of grapes in a juice plant would necessitate the elimination of the barrels which are used in some sections of the country for hauling grapes from the vineyard. It would also necessitate more careful handling methods than are now sometimes accorded to grapes destined for juice.

TABLE II—Effect of Stickers and Spreaders on Arsenical Spray Residue Removal With Hydrochloric Acid

Spreader	Sprayed 1 week prior to Washing. Washed With 0.6 per cent HCL (Per cent As_2O_3 Removed)	Three Standard Spray Applications Washed With 0.33 per cent HCL (Per cent As_2O_3 Removed)
None	88	—
Fish oil	89	86
Fish oil soap	93	80
Sulfonated castor oil	90	83

After 6 months storage, several lots of pasteurized grape juice made from washed fruit were compared by several observers with comparable lots of juice made from unwashed grapes. In most cases no difference in flavor was observed, although in a few cases there was a slight preference for juice made of unwashed grapes. Juice made from grapes which had been washed in acid but not rinsed had a decidedly unpleasant flavor, emphasizing the importance of careful rinsing. Rinsing in lime water, however, resulted in a slightly unpleasant flavor. Washing of grapes was found to produce a slight dilution of the juice due to the water which adhered to the grapes when no attempts were made to dry the fruit. Usually a lowering of about 0.5 was found in the Brix reading of juice as a result of washing grapes.

Effect of washing on keeping quality: The phase of grape washing which presents the greatest problem is the washing of basket grapes for shipment. The handling of wet grapes in baskets has always been considered undesirable because of the danger of mold development. In this investigation an attempt was made to ascertain the efficiency (a) of drying methods and (b) of methods of handling wet grapes to minimize mold development.

A blower with a delivery of 1,150 cubic feet per minute removed only a small amount of moisture from grapes carried on a slatted conveyor moving at the rate of 2 feet per minute. Even the blower of a commercial apple washing machine which delivered 4000 cubic feet of air per minute at a high velocity failed to remove completely the moisture from grapes. The clusters were dried fairly well on the outside but considerable moisture remained on the inside of the clusters.

Grapes destined for shipment have been successfully washed experimentally in trays both in a commercial apple-washing machine of the conveyor type and in a machine especially designed for washing grapes. Grapes have been handled in the latter directly on the conveyor of the machine as well as in trays. However, the use of galvanized metal in trays was found to impart a slight metallic flavor to the fruit in some cases.

The extra handling of the fruit which is necessary in washing in a conveyor machine is a factor which should be considered. In sections where grapes are packed in packing houses, this would probably not be a serious disadvantage. Where grapes are harvested directly into the shipping container, washing the fruit in a machine washer of either of the two types mentioned might not meet with favor; on the other hand, it would be advantageous in some cases to pack the fruit after washing, as this would afford an opportunity to sort out cracked and otherwise defective berries, and thus to put out a better pack.

For many growers the method which seems at present to be most desirable is to dip the baskets of grapes first in an acid solution and then to rinse in water either by dipping the grapes in a tank of water or by thoroughly drenching them with running water. As with other fruits, the acid wash should be changed frequently, and, unless running water is used for rinsing, the rinse water should also be changed frequently. It is suggested that about 2 or 3 gallons of water for rinsing should be provided for each bushel of grapes. The acid wash should be changed before it becomes very dirty. It would probably be necessary to provide at least a gallon of fresh acid solution for each bushel of grapes washed.

TABLE III—Effect of Method of Handling and Size of Container on Mold Development in Concord Grapes Held 1 Week at 70 Degrees F

	4 Quart Basket			½ Bushel Basket	Bushel Basket
	Very Carefully Handled	Carefully Handled	Carelessly Handled	Carefully Handled	Carefully Handled
	Per cent moldy berries				
Not washed	2.1	3.0	16.0	3.3	3.6
Washed	2.2	4.0	35.0	5.0	10.0

It is imperative that grapes to be washed should be carefully handled in baskets of 12 quart size or less although sometimes 16 quart baskets can be successfully handled. Careless handling or the use of large containers such as bushel baskets favors mold development in both washed and unwashed grapes, but especially with washed grapes. This is illustrated in Table III which is typical of the results obtained. Although the figures in Table III do not show much influence of the size of the package on the percentage of moldy berries in unwashed grapes, there was a decided difference in condition in favor of the smaller packages. Some of the fruit in the larger pack-

ages was moist and although many of the berries were not actually moldy, they were starting to sour. This was especially true below the surface layers of washed grapes packed in large packages. When grapes are shipped the percentage of mold in large containers is usually proportionally greater owing to the larger number of cracked berries produced by the combined effect of weight and handling in transit.

The importance of careful handling of grapes both before and after washing can not be too strongly emphasized. Even with careful handling, there is often slightly more mold development in washed grapes. Holding grapes at low temperatures (32 to-40 degrees F) greatly reduces mold development in both washed and unwashed grapes even when carelessly handled although careless handling does result in considerable mold growth even at these low temperatures.

Washed Concord grapes from western Michigan and Concord and Catawba grapes from Sandusky, Ohio, that were packed wet in 12 quart climax baskets have arrived at Washington, D. C., in good condition after shipment by express.

Conclusions

The results of experimental work performed thus far indicate that grapes can be successfully washed in a juice plant for removal of arsenical residue in most cases with only slight modifications of present practices. With grapes which are to be packed in baskets for shipment, it would be preferable to reduce the arsenical load below the tolerance by modification of the spray schedule. If this is impossible, grapes can be washed and shipped wet provided they are carefully handled and are packed in baskets of 12 quart size or less.

Is the Increased Rooting of Wounded Cuttings Sometimes Due to Water Absorption?

By Leonard H. Day, *University of California, Davis, Calif.*

To test the effect of wounding the basal ends of cuttings on the stimulation of root formation, the following methods were used with California privet (*Ligustrum ovalifolium*), quince, and Muscat grapes: (1) A slice of bark and wood was cut out on one side of the lower 2 inches; (2) four slits were made through the bark at the lower end; (3) the outer bark was scraped away from the lower 2 inches; (4) used in case of grape only, a ring of bark $\frac{1}{16}$ to $\frac{1}{8}$ inch wide was taken out 1 inch above the lower end.

The cuttings were planted in February and March, 1932, in a lath house in soil consisting of approximately equal parts of coarse sand and loam. They were watered every week or 10 days as necessary.

At the outset, wounded cuttings made distinctly more rapid growth than unwounded checks. In quince, however, by June the difference was scarcely visible in either root or top growth. Wounded grape cuttings maintained distinct superiority until they were taken up in June, the bark-scraped lot being in the lead, with slicing second, slitting third, and ringing fourth.

The privet buds were nearly open when the cuttings were planted. Before roots formed, the treated cuttings were growing much more strongly than the checks, and by June had made distinctly more root and top growth. The slit specimens made slightly more growth than the sliced, and the latter slightly greater than the ringed.

TABLE I—Amount of Water Absorbed by Desiccated Cuttings in 24 Hours

Treatment	No. of Cuttings	Wt. When Cut (Gms)	Wt. When Planted (Gms)	Wt. After 24 Hrs. (Gms)	Gms. Gained in 24 Hrs.
(1a) Normal cuttings (transverse cuts)	25	96.5	80.85	86.65	5.80
(1b) Normal cuttings (transverse cuts)	25	96.5	80.20	85.45	5.25
(2a) Cuttings with 1 inch slices at base	25	96.4	75.00*	83.00	8.00
(2b) Cuttings with 1 inch slices at base	25	96.5	75.00*	82.90	7.90
(3a) Cuttings with four slits at base	25	96.3	80.45	87.25	6.80
(3b) Cuttings with four slits at base	25	96.3	80.70	86.80	6.10

*Note: Lesser weight due to slice taken out after drying. The respective weights before slicing were 81.2 and 80.8 grams.

The more rapid growth of wounded privet cuttings even before roots were formed suggested that they absorbed water more rapidly than the unwounded and that the increased rooting was not due merely to wound stimulus.

To determine whether moisture absorption is increased by wounding, Bartlett pear cuttings were desiccated, at room temperature, until they had lost about 20 per cent of their weight. They were

then given the wounding treatments, planted in moist sand, taken up the following day and reweighed. Results shown in Table I indicate that at least desiccated cuttings absorb more water if wounded.

In this experiment (Table I) the moisture content of the sand was at or perhaps slightly below field capacity. In other experiments with cuttings planted in sand low in moisture content, wounded cuttings absorbed two to three times as much as the unwounded.

Other experiments tested the effect of covering wounds with clay. In these, 45 grams of a finely powdered China clay and 55 grams of water made a paste of such consistency that a layer about 1 mm thick readily adhered to the cuttings. In one experiment, 25 untreated cuttings with transverse cuts gained 1.3 grams in 12 hours, and 25 similar cuttings with the bottom cuts covered with clay paste gained 14.2 grams. This was in sand rather low in moisture content. Only 3.5 grams of the clay paste were used on the lot of 25 cuttings. Another test showed greater absorption with clay paste over sliced and slit cuts than over transverse cuts. Cuttings with the clay lightly rubbed into the slits absorbed water more rapidly than any others.

Since a clay covering over the bottom cut might prevent proper callusing or formation of root initials with some species, absorption tests were made with the slits and slices terminating above, rather than extending to, the base. In these cuttings, the slits and slices began ¼ inch above the bottom cut and extended upward approximately 1 inch. As in the previous experiments, the slits passed clear through the bark and barely into the wood. Cuttings thus treated absorbed as freely as those with similar wounds extending to the base.

A paste made of finely powdered lime carbonate gave as large increases in absorption as did clay. This suggests that other substances could be used either alone or with clay in experiments to stimulate formation of roots.

During the first week of September, 1932, tests were conducted with leafy cuttings treated by the various wounding methods, both with and without the clay paste. During days of high temperature and low humidity the cuttings with clay-covered slits remained turgid while all others wilted. Leafless pear cuttings with clay-covered slits broke into new shoot growth, but those with the other treatments remained dormant.

Privet cuttings planted on September 24 and taken up on November 24 showed no callus formation and no roots in normal cuttings; in similar cuttings with clay paste over the bottom cuts a little callus formed and a few roots were pushing through the bark; those with clay-covered slits above the bottom cut but no clay over the lower cuts, made much greater callus formation and all formed roots; four out of the 10 had roots 1 to 1.5 inches long. Normal cuttings did not remain turgid during hot days and became slightly chlorotic and some of the leaves abscised. Those with clayed slits remained turgid even during drying winds which continued over a period of 5 days.

The Influence of Rooting Media on the Character of Roots Produced by Cuttings

By J. C. Long, *U. S. Department of Agriculture, Washington, D. C.*

CUTTINGS of many plants, when rooted in sand produce coarse, brittle, sparsely branched roots while those rooted in peat moss produce very slender, flexible, and usually well branched roots. Apart from scientific interest in this difference, the character of the roots becomes of practical importance in potting cuttings for, if the roots are coarse and brittle, many are broken. This results in severe check or perhaps complete loss. Although peat moss will in most cases induce the development of a root system satisfactory for potting, cuttings of many plants do not root in sufficiently high percentage in this medium, but may do so in sand.

Fig. 1. *Hedera helix*. Left to right: rooted in sand, in mixture and in peat moss.

It was hoped by this study to find the factors responsible for development of slender, flexible, or of coarse brittle roots. With these known it might be possible so to modify sand as to secure a root system desirable for potting.

Forty-three kinds of cuttings were rooted in sand, peat moss, and a mixture of the two. Of these, 30 (list A) produced a more slender, and generally a more branched root system in peat moss and the mixture than in sand. (See Fig. 1 and Table I.) Failure of the remaining 13 (list B) to show observable differences may be explained by the fact that they normally produce fine roots even in sand.

TABLE I—Averages of Counts of Roots of Hedera Helix (English Ivy) in Different Media

Media	Number Cuttings Rooted	Primary Roots		Secondary Roots		Total Length (Inches)
		Number per Cutting	Total Length per Cutting (Inches)	Number per Cutting	Total Length per Cutting (Inches)	
Sand.......	25	7.24	5.74	15.08	3.42	9.16
Mixture....	20	5.75	8.16	31.00	7.35	15.51
Peat Moss..	25	7.04	13.85	43.68	7.50	21.35

List A. Plants Showing Differences in Root Character. (Arranged in Order of Greatest Differences).

Pyrus communis (var. Rymes), *Hedera helix, Ligustrum ovalifolium, Forsythia intermedia, Rosa multiflora,* (var. Phila. Rambler), *Jasminum stephanense, Vinca major elegantissima, Picea excelsa compacta, Lonicera pileata, Juniperus chinensis, Juniperus horizontalis, Picea engelmanni, Thuja occidentalis, Prunus cerasifera myrobalana, Taxus cuspidata, Buxus suffruticosa, Buxus sempervirens handsworthi, Hydrangea paniculata grandiflora,* Chrysanthemum (Several vars.), *Cotoneaster salicifolia, Lonicera muscaviensis, Escallonia donardensis, E. edinensis, Euonymus japonica, Pyrus malus* (var. Missouri Flat Pippin), *Pinus taeda, Chamaecyparis lawsonia fletcheri, Ilex opaca, Coleus blumei, Juniperus communis suecica.*

List B. Plants Showing No Observable Difference

Cotoneaster horizontalis, Begonia mangifera, Lonicera sp., Azalea kaempferi, Spiraea vanhoutei, Erica stricta, Populus simoni, Bryophyllum pinnatum, Pelargonium zonale, Salix nigra, Dianthus caryophyllum, Philadelphus coronarius, Tradescantia fluminensis.

From the first list of plants, *Hedera helix, Ligustrum ovalifolium,* and *Forsythia intermedia* were selected for further study of medium influence. The contrasting characteristics of sand and peat moss suggest the following factors which might influence root characters, namely, acidity, presence of nutrients, aeration, moisture, and size and shape of particles. Factors such as intensity and duration of light, length of day, temperature, leaf area, and size of the cuttings were identical in all comparable media tests.

Acidity and Nutrients in the Media. Sand was watered with acetic acid-sodium acetate solution buffered at pH 4.6 to approximate the acidity of peat moss. In other experiments peat moss was treated with calcium hydroxide to attain the neutrality of sand. The roots produced in acid and in neutral sand as well as those produced in acid and neutral peat moss, however, were still characteristic of the respective media. Treatment of sand with Shive's three-salt nutrient solution also failed to alter the root character.

Cuttings were presoaked in acid and nutrient solutions 24 hours and then placed in sand while others were actually rooted in these solutions in a further test of the opinion that the acid and nutrient contents of the medium does not alter root character. In all cases tap water was used as a check. The results confirmed this opinion.

Aeration and Moisture Content of the Media. Determinations of the air and moisture content of peat moss and sand of moisture content approximately optimum for rooting showed that peat moss contains over twice as much air and three times as much moisture as sand, on a volume basis. In order to determine which, if either, of these two factors is responsible for the character of the roots produced, a series of experiments were designed to alter one while holding the other constant. Cuttings were rooted in glass tubes

with water kept at different heights. This varied the air at the base of the cutting without altering the moisture (1). In other experiments flasks of water were used as a rooting medium one aerated from a pressure tank with another non-aerated as a check. Finer roots were secured where air was not at a minimum.

Three galvanized tanks, of different heights, without tops or bottoms were set upright in trays filled with water. These tanks were filled with sand, and capillary action kept the moisture content in each individual tank fairly constant but provided a different moisture for each depending upon the height of the sand above the water. Cuttings were rooted in these tanks. Other experiments involved the use of several different media placed in large clay pans and held at different but constant moisture conditions. In all cases finer roots were secured in the media with the higher moisture content.

When peat moss was kept at a low moisture content to approximate that of "optimum" wet sand (on a volume basis) the coarseness of the roots in the peat moss approached those in sand. Furthermore, cuttings set deep in sand and well packed produced finer roots than those set shallow and unpacked.

Transferring cuttings from one medium to another after 1 week, 2 weeks, and when roots were ½ inch long, showed that the media did not influence the roots until they had actually protruded from the cutting.

Aeration of the media and moisture of the media have both given evidence of influence on root character. Determination of which of these factors is responsible is not simple because as one is increased or decreased the other is inversely varied. Experiments designed to hold one constant while the other is varied have been difficult.

The experiment in which roots were produced in water at different heights in order to vary the air content seems to indicate that low aeration makes for finer roots. On the other hand peat moss, which produced finer roots than sand, contains at optimum moisture conditions twice as much air per volume as sand.

Peat moss at optimum moisture conditions also contains more water on both weight and volume bases. When cuttings were rooted in peat moss which contained on a volume basis only the amount of water that sand contained, the roots were similar to those produced in sand. This indicates that the amount of water is the important factor, for although in this case the air in the peat moss is increased, even when considerably wetter, peat moss still contains more air than sand. A further increase in the air, it would seem should make for still finer roots instead of coarser ones.

There is still possibility that air is an important factor. The fibrous nature of the peat moss particles and their close adherence to the roots allow each root to be more completely bathed in a film of water than is possible with sand. Under these conditions it appears possible that the root surface in peat moss is not as well aerated as in sand with its large intergranular spaces, even though

peat moss contains more air. Only when peat moss was very dry, so dry rooting could barely take place, was aeration at the root surface increased to approximate that of sand. Roots produced under this condition resembled those from sand.

This theory regarding the specific factor in peat moss which is responsible for the nature of the roots produced, finds support in the work of Livingston and Free (2) where roots of higher plants, grown in soil with most of the oxygen replaced with nitrogen, were long and slender. If this is the case, the poor aeration provided the root surface by peat moss may explain certain anatomical differences found. Microscope preparations showed clearly a more pronounced endodermis in roots from sand. It is suggested (3) that the endodermis is formed when certain fatty waste compounds moving toward the outside encounter air moving in and are oxidized and deposited as the Casparian strip. The endodermis is thought to offer some resistance to the initiation of secondary roots which have their origin in the pericycle just within the endodermis. The poor development of endodermis found in roots growing in peat moss was accompanied by increase in branch roots. Cortical cells were narrower and longer in the roots from peat moss, which accounts for the very slender roots found in peat moss. No physiological explanation of this can be offered at this time.

From a practical standpoint, in order to obtain the fine roots characteristic of peat moss, it would not be feasible to water sand sufficiently without injury to the cuttings. Firming the medium, setting cuttings deep, and use of short, slender cuttings may aid in securing more fibrous roots in sand.

Size and Shape of Particles. Different sizes of particles ranging from fine sand to fine gravel were used as rooting media. For a greater part of the year there were no observable differences in root character, but during the long hot summer days cuttings in the coarser media produced finer roots. At this season it was necessary to water the coarser medium much oftener since it was not very retentive of moisture. Moisture determinations on both weight and volume bases, showed that the fine gravel contained more water than the sand. Therefore, these differences seem explainable on the basis of different amounts of water and air in these media rather than from any direct effect of size of particle. Cuttings rooted in a sharp quartz sand and those rooted in a water worn smooth sand had similar roots.

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Stimulation of Grape Bench Grafts

By H. E. Jacob, *University of California, Davis, Calif.*

BENCH grafting of unrooted cuttings is the most common means of producing vines of vinifera grape varieties on phylloxera-resistant rootstocks. A number of stocks, excellent in other respects, give poor nursery stands from bench grafts. Promising experimental results have been obtained with certain of these stocks by stimulative treatment of the stock cuttings prior to the grafting.

Stocks Employed.—For sake of brevity abbreviated forms of the names or numbers referring to particular hybrids are used in the tables and discussion. These abbreviations signify as follows:

St. Geo.—Rupestris St. George.
3306—Riparia x Rupestris, 3306 (Couderc).
3309—Riparia x Rupestris, 3309 (Couderc).
A x R No. 1—Aramon x Rupestris Ganzin, No. 1 (Ganzin),
A x R No. 9—Aramon x Rupestris Ganzin, No. 9 (Ganzin).
1202—Mourvèdre x Rupestris, 1202 (Couderc).
1616—Riparia x Solonis, 1616 (Couderc).
Dogridge—Rupestris x Candicans (Munson).
420-A—Riparia x Berlandieri, 420-A (Millardet and de Grasset).
157-11—Riparia x Berlandieri, 157-11 (Couderc).
41-B—Chasselas x Berlandieri, 41-B (Millardet and de Grasset).
110-R—Rupestris x Berlandieri, 110 (Richter).

Stimulation of Hot Room Forcing of the Stock Cuttings Prior to Grafting.—The stock cuttings were packed, in a moist mixture of three parts sawdust and one part fine granular charcoal, in boxes approximately 14 x 19 x 24 inches. The boxes, when filled, were

TABLE I—Stimulation of Grafts by Hot Room Forcing of Stock Cuttings, as Measured by Percentage of 1-Year-Old Vines Obtained from Bench Grafts

Scion Variety	Stock	Stocks in Warm Room 10 Days before Grafting	Check
Emperor	41-B	77	45
Alicante Bouschet	41-B	52	28
Ohanez	41-B	65	18
Cornichon	420-A	59	32
Alicante Bouschet	420-A	20	2
Ohanez	420-A	65	2
Cornichon	110-R	68	40
Alicante Bouschet	110-R	40	12
Ohanez	110-R	54	47

dipped into water at approximately 90 degrees F, which thoroughly wet and warmed the contents. After the excess water had drained from the boxes, they were placed in a warm callusing room (75–85 degrees F) for 10 days prior to grafting. Check lots were stored out of doors in moist sand or rice straw and soaked in cold water for 24 hours prior to grafting. After grafting, all lots were handled

as nearly alike as possible with respect to callusing, hardening, and planting in the nursery. As measured by the percentages of 1-year-old No. 1 rooted grafts obtained from each combination used in 1929 and 1931 (Table I), each of the stocks used shows marked benefit from the forcing treatment.

Analysis by Student's method yields odds of over 4000 to 1 in favor of the lots held in the warm room.

Hot Water.—Lots, of 100 stock cuttings each, were immersed in water held at 122 degrees F for 10 minutes, 15 minutes, 20 minutes, and 25 minutes, respectively. Check lots were soaked for 24 hours in cold water. Lots of another series were immersed for 3 minutes in water at 129 degrees F. All lots were then grafted to Sultanina (Thompson Seedless), callused, and planted in the usual manner. Table II shows the number of 1-year-old No. 1 rooted grafts produced from each lot of 100 grafts in 1932. The figures indicate that some benefit has probably been obtained, particularly with 41-B, which gave best results when soaked for 10 minutes at 122 degrees F. The 420-A and 1202 responded best to the 3-minute treatment at 129 degrees F. Though indicative of beneficial results the response obtained is of much smaller magnitude than that reported by Birk (1) who used 1202 grafted to Riesling. He reported 64, 94, 89, and 84 per cent from lots held at 50 degrees C (122 degrees F) for 10, 15, 20 and 25 minutes, respectively, as compared with a check of 38 per cent.

TABLE II—EFFECTS OF HOT WATER STIMULATION OF ROOTSTOCK CUTTINGS ON NUMBER OF 1-YEAR-OLD VINES PRODUCED FROM 100 BENCH GRAFTS

Stock	Water at 122 Degrees F				129 Degrees F	Check
	10 Min.	15 Min.	20 Min.	25 Min.	3 Min.	
41-B..........	35	27	32	29	25	11
420-A.........	35	32	32	29	40	29
1202..........	47	46	37	39	50	38

Stimulation by Chemical Means. — Winkler's work (2) on the chemical stimulation of vine cuttings suggested the possibility of chemical stimulation of bench grafts. Manganese sulfate and "Semesan" were used in various concentrations. Stock cuttings were soaked in the solutions before being grafted, and in other tests the boxes containing the grafts, packed and ready for callusing, were partially immersed in the solutions so that the stocks but not the scions or the unions were subjected to the action of the solution. Still other tests were made in which the entire contents of the boxes were wet with the solutions. Semesan in concentrations of 0.001, 0.01, 0.05 and 0.1 per cent of the active ingredient (Hydroxymercurichlorophenol, according to the label), failed to produce any significant improvement but did control the growth of molds during the callusing period.

Tests with $MnSO_4$ yielded somewhat more promising results. Table III shows the results obtained by soaking the stock cuttings for 24 hours in 0.001 Molal $MnSO_4$ solution before grafting. The data for 2 years, 1927 and 1928, have been combined and are expressed in percentages.

TABLE III—STIMULATION OF BENCH GRAFTS BY SOAKING THE ROOTSTOCK CUTTINGS 24 HOURS IN 0.001 MOLAL $MnSO_4$

Stock	Per cent 1-year-old Vines from Bench Grafts			
	Muscat		Emperor	
	Treated	Check	Treated	Check
St. Geo	75	59	61	50
3306	62	64	74	63
3309	65	42	61	61
A x R No. 1	29	39	52	39
A x R No. 9	67	66	62	58
1616	21	24	23	36
Dogridge	37	18	27	13
420-A	38	23	30	20
41-B	65	44	34	38
157-11	62	50	42	56
Mean of all stocks	25.1	42.9	46.6	43.4

The Muscat grafts on all stocks, except 3306, A x R No. 1 and 1616, show small differences in favor of the treatment. Though these three stocks show differences in favor of the checks, analysis of the data for all of the Muscat grafts by Student's method gives odds of 53 to 1 in favor of the treated lots. Similar analysis of the data obtained from the Emperor grafts yield odds of only 4.7 to 1 and when all the data for the Muscat and Emperor grafts are used the odds are 73 to 1 in favor of the treatment. Though the general response to the treatment appears to be positive it is of small magnitude and not as consistent as might be desired.

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The Source of Apple Seedlings in Relation to Blotch Infection

By J. A. McClintock, *Purdue University, Lafayette, Ind.*

NEARLY 10 years ago Gardner and Jackson (1) called attention to infected apple seedlings as an important source of blotch infection of nursery and orchard trees. That such seedlings are not merely an occasional source of infection is indicated by the fact that the writer has found blotch cankers on apple seedlings from midwestern nurseries each year since 1923. The number of seedlings showing blotch cankers at the end of the first growing season varied from year to year as illustrated by a maximum of 47 per cent infected seedlings in 1931, and 14 per cent in 1932. Regarding such canker infections, Gardner (2) says, "It should be remembered that if there are cankers visible on some trees all may have been exposed to infection, and may be carrying invisible leaf scar infection."

On bearing trees, Gardner (3) found that 95 per cent of the leaf scar infections did not appear on the twigs until the second season. If the same percentage holds true in seedlings, i. e., if cankers which appear the first year are only 5 per cent of the total infections, it is reasonable to expect a heavy infection the second season, even though the visibly infected seedlings had been culled out. A test to determine the importance of blotch infections not showing as cankers the first season was conducted at Purdue University during 1932, using seedlings from midwestern nurseries. These seedlings were lined out in rows in fairly level soil several hundred feet from any source of inoculum. Early in the summer cankers began to appear and, in all cases, they developed near leaf scars. These findings indicate that the cankers which developed on the seedlings in 1932 came from the late petiole infections in the nurseries in 1931 and spread down across the abscission layers and into the scar tissues as described by Kohl (4). The results of this test showed that the normal infection of apple seedlings is considerably higher than one would suspect from the number of cankers on seedlings at the end of the first growing season.

Gardner, Greene, and Baker (5) report blotch canker infection both on stems and on roots of seedlings shipped from Kansas to Indiana, and the writer (6) has made similar observations on seedlings shipped to Tennessee nurseries. With invisible blotch infections present, it would be impossible for nurserymen to cull all diseased seedlings from shipments intended for whip grafting. Therefore, crown and root infections which developed on the stock during the next growing season might infect the scions either by direct mycelial growth or by spores developing on the infected stocks.

Before European seedlings were excluded by Federal quarantine, nurserymen assured themselves of blotch-free seedlings by import-

ing French crab seedlings. The soundness of that practice was verified by the writer's examination of thousands of seedlings from France in which no cases of blotch appeared or developed when they were used for grafting or lined out for budding. That such freedom from infection of the European grown seedlings was not due to any inherent resistance of the French crab seedlings to the blotch fungus is proved by the fact that most of the severely blotch infected midwestern seedlings have for many years been grown from French crab seed imported from Europe.

With no improvement in the blotch situation during the past 10 years as far as midwestern apple seedlings are concerned, and with the European supply of blotch-free seedlings cut off by Federal quarantine, American nurserymen and orchardists are entitled to a practical solution of this blotch problem. To this end, we should profit by the European example that blotch-free seedlings are most satisfactorily produced in places where there are no centers of blotch inoculum.

According to the records of the Federal Plant Disease Survey (7), apple blotch has not been reported from states west of Colorado, except on seedlings shipped into that region from farther east. These records indicate that in the states from Colorado west there are no natural sources of inoculum of the blotch fungus, such as native crab apples, and no artificial sources such as old blotch-infected orchards. Under these conditions, it is to be expected that in this blotch-free area apple seedlings can be produced as free from infection as those produced in Europe. In confirmation of this point, it is desirable to record that for several years the writer has examined, in detail, commercial shipments of apple seedlings grown in west coast states, and has not found any blotch infection or seen blotch develop on such seedlings when lined out for budding.

The results of these studies indicate that blotch-infected seedlings are a potential source of disease to nurserymen and orchardists, as first reported almost 10 years ago; that seedlings showing cankers when received from the nurseries are only a portion of those actually infected; and that blotch-free seedlings may be grown in the Pacific coast states where apparently there are no disease centers from which seedlings may become contaminated.

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Some Experiments in Budding Fruit Tree Stocks

By W. H. Upshall, *Vineland Station, Ontario, Can.*

EXPERIMENTS in budding fruit tree seedlings in the nursery row were started at the Ontario Horticultural Experiment Station in 1928. No. 1 French seedlings were used except in peaches, for which the stocks were Elberta seedlings. The soil on which they were lined out for budding is a fine sandy loam of good fertility underlaid with clay at 4 to 6 feet. Buds from one bearing tree each of McIntosh apple, Bartlett pear, Reine Claude plum, Windsor Cherry, and Vedette peach were used. All budding was done by the writer and in any one year the buds were tied by the same person. Except in the bud ties experiment, raffia was used in 1928 and 1929, and rubber strips, 3½ x $\frac{3}{32}$ inches, were used during the period 1930–32.

Results with Cherries

Time of Budding Cherries: In Ontario nurseries the take of cherry buds is often unsatisfactory. It was suggested that the method or time of budding might be a deciding factor. Complete results of four years' work with Mahaleb and 3 years' work with Mazzard are now available. Each year, 30 seedlings of each stock were budded at about 10-day intervals from early July to mid-September. In each stock a plate bud and a shield bud were inserted, one on the west side, the other on the north.

The results are given graphically in Fig. 1. Some buds united

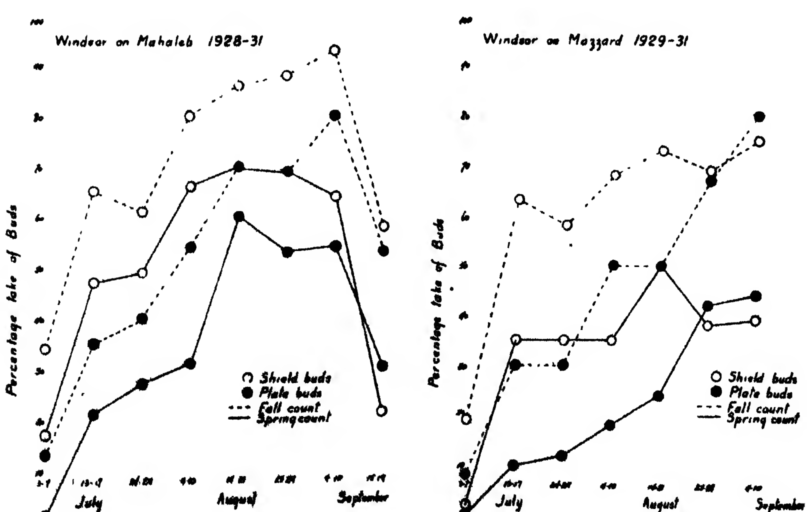

Fig. 1. The Take of Buds on Mahaleb and Mazzard Cherry Stocks as Influenced by Time and Method of Budding.

with both stocks even at very early and very late dates. The broken lines representing the count of buds which had apparently taken a few weeks after budding, are included in order to show the considerable winter mortality of buds, especially on Mazzard. Though in all cases grown alongside the Mahaleb stock, Mazzard has not made as satisfactory growth even when there was no leaf spot infection, and it has not taken the bud as well as the former. It has been stated that plate buds give better results than shield buds on cherry stocks; this has not been true in these experiments except for the latter part of the budding period. Apparently shield buds can be used successfully on Mahaleb stocks any time during August or early September but on Mazzard stocks the optimum time seems to be confined to mid-August. In using plate buds the optimum time seems to be somewhat later in both stocks.

Spraying Cherry Stocks: Mahaleb stock is comparatively disease resistant while Mazzard is very susceptible to leaf spot and mildew. The leaf spot disease is usually the more serious and often induces a very early leaf fall and premature tightening of the bark, resulting in a poor stand of buds. Unfortunately, attempts to control these diseases have given unsatisfactory results. During the period 1929–1931 when there was practically no leaf disease on Mazzard stock sprays were unnecessary while in 1932, a summer of frequent rains, the three regular 1–40 lime-sulphur sprays, at shuck fall and 12 and 24 days thereafter, failed to give satisfactory control. When we add to this the fact that both 3–6–40 Bordeaux and 1–40 lime-sulphur have given more or less leaf injury, particularly as a result of the first spray, it must be conceded that the outlook for the successful production of cherry trees on Mazzard stock in our district is not very bright. Spray injury occurring in the absence of leaf spot has resulted in a poorer stand of buds on sprayed than on unsprayed stock. In 1929 and 1930, sprayed and unsprayed stocks of Mazzard and Mahaleb were budded. Two-year average percentage take of buds was as follows: Mazzard, sprayed, 24.6; unsprayed, 48.3; Mahaleb, sprayed 18.6; unsprayed, 48.0. In 1931 the addition of iron sulphate to the lime-sulphur spray increased slightly rather than reduced the spray injury.

Ties for Buds

For four years rubber strips have been used in comparison with raffia as ties for buds. Table I shows that on the whole the grey rubber strips have given a slightly better stand of buds than the raffia. Some nurserymen have been afraid to use them because they do not cover the wound as completely as raffia, but, judging from our results, this is not a disadvantage. Heavier rubber strips, $4 \times \frac{3}{16}$ inches, were used in one experiment but as they gave no better results than the smaller, less expensive strips, they were not used again. When the time of preparing raffia as ties is considered, there is very little difference in cost per tie between rubber strips and raffia. A further advantage of using rub-

TABLE I—RUBBER STRIPS AND RAFFIA AS TIES FOR BUDS (NUMBER OF STOCK IN EACH LOT 17 TO 100, AVERAGE 49. FIGURES EXPRESS PERCENTAGE OF BUDS GROWING IN THE SPRING FOLLOWING BUDDING)

	1929		1930		1931		1932	
	Rubber Strips	Raffia	Rubber Strips	Raffia	Rubber Strips	Raffia	Rubber Strips	Raffia
Apple. ...	85	74	97	100	100	88	—	—
Pear.......	92	71	97	87	72	56	—	—
Plum......	54	67	40	53	70	61	—	—
Cherry. ...	80*	15*	—	—	38	37	13*	2*
Peach... ..	79	79	—	—	71	67	99*	92*

*Counts taken 3 weeks after budding.

ber strips is the saving of labor in that no cutting away from the stock is necessary after the bud has united. Under our conditions it would seem advisable to use rubber strips instead of raffia for tying buds.

PACKING BUD STICKS FOR SHIPMENT

Having had very poor success with buds shipped in from a distance and as there seemed to be a decided lack of agreement as to the best method of packing bud sticks for shipment, the writer began some simple tests in 1929. Table II shows that seasonal

TABLE II—METHODS OF PACKING BUD STICKS FOR SHIPMENT (BUD STICKS HELD AT ROOM TEMPERATURE 1 WEEK. FIGURES EXPRESS PERCENTAGE OF BUDS GROWING IN SPRING FOLLOWING BUDDING, 25 BUDS BEING USED IN EACH STOCK EACH YEAR)

Stock	Year	Wet Paper	Wet Moss	Moist Moss	Waxed 190 Degrees F	Oiled Paper	Leaves on	Not Stored
Apple ...	1929	—	—	—	—	—	97*	—
	1930	100	77	62	—	94	93†	—
	1931	100	96	96	80	96	96	100
Pear	1929	16	8	68	96	—	—	—
	1930	67	53	79	—	87	—	—
	1931	52	24	32	76	36	48	80
Plum.....	1929	9	16	70	30	—	—	—
	1930	7	33	7	—	40	—	—
	1931	72	44	92	44	80	—	92
Cherry....	1929	24	36	32	24	—	—	—
	1930	10	0	0	—	0	—	—
	1931	44	24	24	56	16	92	87
Peach.....	1931	40	12	24	76	56	36	—

*68 buds packed for 3 days. †28 buds packed 11 days.

conditions make a great difference in the results obtained from the various treatments. In the "wet paper" and "wet moss" treatments excess water was allowed to drain off while the "moist moss" was hand squeezed as dry as possible. Sphagnum moss was used in

all experiments. The "waxed" lot was dipped into parawax at about 190 degrees F and withdrawn *as quickly as possible.* No injury occurred at this high temperature provided the sticks were removed immediately. At this temperature the wax forms a thin coat which adheres well and does not seriously interfere with later budding operations. The "oiled paper" lots were wrapped first in oiled paper and between this wrap and another one, moist moss was used. This is similar to a method recommended in U. S. D. A. Cir. 323.

The lots noted as "leaves on" were distinct from other treatments in that the leaves were left intact and not cut off near the base of the petiole. It is very important that the leaves be kept from wilting at all times. The shoots were placed upright individually in a heavy cardboard box containing *an abundance of moist moss* and the box was wrapped in a heavy waterproof paper. Under the other methods of packing the "handles," lower portions of the petiole, drop off in a few days time; as a result the operation of budding is made considerably more difficult and there is danger of injuring the bud on placing it into position. It was found that the petioles in the "leaves on" treatment remained intact for from 2 to 7 days longer than with any other treatment. After being wrapped up for 7 days the handles, except in peaches, were generally usable in inserting the buds. For peaches there is some doubt about the advisability of using this packing method. The waxing treatment appears to be much better.

The waxed lots come second in retention of handles. For shipments which are likely to be on the way more than 10 days and especially when they have to pass through the hands of customs and plant inspection men in going from one country to another the waxing method is probably the safest. Table II shows that apple buds withstand storage conditions better than other fruit tree buds. As for the other treatments, the order of decreasing value seems to be "oiled paper," "moist moss," "wet paper," "wet moss." This order suggests that prolonged contact with water in liquid form may injure the bud.

Variability in Citrus Propagated by Cuttings and by Budding

By F. F. HALMA, *Citrus Experiment Station, Riverside, Calif.*

IT is generally assumed that the degree of variation in citrus trees is closely related to the inherent variation of the rootstock, and that if, therefore, seedling rootstocks were eliminated (that is, if trees were propagated by or on cuttings, or layers), variability would be reduced to a minimum.

Opportunity was utilized to study the comparative variation of cuttings and budded nursery trees which were being grown on the Experiment Station grounds for subsequent testing under orchard conditions. The data herewith presented deal with the Valencia and Washington Navel oranges (*Citrus sinensis* Osbeck), the two most important varieties in California.

The buds and cuttings were obtained from 13 selected Valencia and 10 Washington Navel orange trees located in the orchards of the East Highlands Orange Company, East Highlands, California.[1] The cuttings were planted in the propagating bench in January, 1929, and transplanted to the nursery the following March (1). The seedling rootstocks for the budded trees were sweet orange (*Citrus sinensis* Osbeck), of three lots, namely, Lot I, which came from one seedling tree. Lot II, which came from several Valencia orange trees, and Lot III which was of unknown origin, probably a miscellaneous collection. The seeds were planted in the spring of 1927, the seedlings transferred to the nursery in the spring of 1928 and budded in October, 1929. The following spring the tops of the seedlings were cut off to force the buds into growth. Because most of the cuttings were too small for planting in the orchard in 1931 the budded trees were held in the nursery until the spring of 1932, at which time they were "2-year-old buds" with a root system nearly 5 years old. Trunks of scions and of cuttings were measured 20 inches above the ground in November, 1931.

The measurements, expressed as cross-sectional area of the trunk in square centimeters, are summarized in Table I. The Valencia orange trees were grouped on the basis of the three rootstock lots and only those cuttings having the same parentage as the scions of the budded trees were used for comparison. In two of the groups the cuttings show a greater coefficient of variation than the budded trees, while in one the situation is reversed, and in the Navel orange trees there is practically no difference in variability. In view of the difference in procedure of the two methods of propagation it is doubtful whether any of the differences in variability

[1]The writer wishes to express his appreciation to the East Highlands Orange Company for permission to cut the material, and to Mr. J. C. Perry for making yield and other records available.

are significant. The important point, however, is that as far as these nursery trees are concerned the cuttings did not show greater uniformity than the budded trees.

TABLE I—TRUNK CROSS SECTIONAL AREA AND CORRELATION OF CROSS SECTIONAL AREA OF SEEDLINGS AT TIME OF BUDDING WITH THAT OF SCIONS 2 YEARS LATER

	Population	Mean Area (Sq. Cm)	Standard Deviation	Coefficient of Variation	Correlation
		Progenies of 3 Valencia Orange Trees			
Cuttings	67	3.4±.12	1.4 ±.08	41.2±2.8	
Budded	42	4.8±.16	1.5 ±.11	31.3±2.5	
Stock (Lot I)	42	1.2±.03	0.25±.02	21.6±1.7	
Stock and Scion					.05±.10
		Progenies of 6 Valencia Orange Trees			
Cuttings	117	3.6±.07	1.1 ±.05	28.2±1.4	
Budded	85	4.4±.11	1.5 ±.08	34.1±2.0	
Stock (Lot II)	85	1.3±.03	0.39±.02	31.2±1.8	
Stock and Scion					.03±.07
		Progenies of 4 Valencia Orange Trees			
Cuttings	94	3.3±.10	1.4 ±.07	42.4±2.4	
Budded	66	5.9±.16	1.9 ±.11	32.2±2.1	
Stock (Lot III)	66	1.9±.03	0.35±.02	18.0±1.1	
Stock and Scion					−.10±.08
		All Valencia Trees Combined			
Cuttings	278	3.5±.04	0.95±.03	27.1±0.8	
Budded	193	5.0±.09	1.80±.06	35.6±1.4	
Stock (Lots I, II, III)	193	1.4±.03	.57±.02	39.9±1.6	
Stock and Scion					.23±.05
		Progenies of 10 Washington Navel Orange Trees			
Cuttings	146	2.2±.04	.78±.03	35.5±1.6	
Budded	103	5.2±.11	1.70±.08	32.7±1.7	
Stock (Lot III)	103	1.6±.04	.59±.03	36.2±1.9	
Stock and Scion					.12±.07

There are, of course, many factors which may be assumed to contribute to variation of the two types of trees. The only index which was studied in this experiment was the relation between size of rootstock at time of budding and size of 2-year-old scion trunk. Judging from the correlation values obtained (Table I), it would seem that the size of the rootstock was of no significance.

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Factors Influencing the Variability of Apple Trees in the Nursery Row. I. Time of Bud Start

By F. E. Gardner, *U. S. Department of Agriculture, Washington, D. C.* and F. B. Lincoln, *University of Maryland, College Pk., Md.*

VARIABILITY among orchard trees has been the subject of numerous researches not only because of its obvious practical aspects in fruit production but also because it must be considered in the interpretation of most experimental field data. Inasmuch as size differences in bearing orchard trees have been traced back to size differences at planting time (3) considerable attention has been focused on the possible causes of variability in the nursery row. The inherent vigor and the size of the rootstock, the source and condition of the budwood, and the method of propagation are among the factors which have been considered.

Within any given lot of budded seedling apple stocks the earliness and vigor of starting of the inserted bud may be, to some extent, an index to the size of whip which will be produced (2). Whether the earliness of starting, *per se*, is responsible for greater whip growth, or whether early starting is merely an expression of some other factor of the stock or of the bud or perhaps in the union of the two, has not been made clear.

To gather more evidence on this relationship it was planned artificially to advance or retard, if possible, the starting of the bud. Any resulting influence on the size of the yearling apple trees produced would indicate that time of starting, in itself, is probably causal, while alteration of starting time without altered size of tree would point to the operation of other factors.

Variation in the absorption of the sun's heat during the late winter and early spring appeared to be a possible way of regulating the starting of the buds. To this end, approximately one-half of the total number of the stocks available had been budded, according to common practice, on the west side; the remainder on the east. Black and white paints were prepared by adding lamp-black and lime, respectively, to shellac. In early March these were applied over the inserted buds (both east and west) and on the stocks to the ground line on the side where the bud was present. A third of the stocks were left unpainted. Black, white, and unpainted stocks, as well as those budded east and west, were systematically distributed throughout the planting to compensate for any soil variability.

As a measure of the earliness of bud start, which varied from plant to plant and over a period of 10 days to 2 weeks, arbitrary values from 1 to 6 were assigned to each bud, indicating its stage of advancement on April 29, as follows: (1) Bud still entirely dormant or perhaps swelling; (2) bud starting to push out—green tips beginning to show; (3) leaves not unfolded, but ½ inch out; (4)

leaves not unfolded, but 1 inch out; (5) leaves unfolding and shoots 1 inch long; (6) shoots 1½ to 2 inches long.

The stock used in this work was a clon, Spy 227, developed by G. E. Yerkes, from a seedling of Northern Spy. They were budded to McIntosh in 1931 with buds from a single large tree. During the summer of 1932 the trees were carefully kept to an unbranched whip so that height could be used as a measure of their growth.

TABLE I—TREATMENT AND RELATIVE START OF BUDS IN RELATION TO ULTIMATE HEIGHT OF WHIPS

Bud Treatment	Number Trees	Average Start of Bud	Average Height Whips (Ins.)	Correlation (Start—Height)
Black (West)...	96	3.864±.068	50.67±.45	+.286±.063
White (West).........	97	3.470±.076	48.76±.54	+.356±.060
Check (West).........	90	3.866±.083	50.57±.46	+.323±.064
All (West)	283	3.73 ±.044	49.98±.28	+.323±.036
Black (East)	79	4.050±.079	48.21±.58	+.198±.072
White (East)..	82	3.752±.084	48.50±.41	.000— —
Check (East)....... ..	73	4.342±.069	50.93±.55	+.045±.078
All (East)..	234	4.04 ±.048	49.16±.30	+.009±.040

Table I shows that black color did not induce the buds to start earlier than the unpainted checks. There is some evidence, however, that white retarded the buds on both east and west sides, although the differences, when compared with unpainted buds, are not far above the borderline of significance. The east buds started earlier than the corresponding color on the west, and the difference in the case of the totals becomes of definite statistical significance when considered in relation to the low probable errors involved. Because the nursery rows in this experiment do not run exactly north and south but instead a little to the east of north, the path of the sun permits more hours of light to the "east" side of the stocks than to the "west" side. This difference in light is further widened due to an elevation and woods to the west. However, if greater heat absorption on the east side is responsible for the earlier starting it is difficult to explain the apparent lack of influence of black color—unless the natural, roughened bark has equal heat absorptive power.

Despite the advanced starting time on the east side, the height of the whips did not increase. Evidently, time of starting is not causally related to amount of whip growth but is simply an expression of some more obscure causal factor or factors.

The coefficients of correlation between time of starting of the buds and height of whips on the west side are typical of those already reported (2) for seedling stocks. The absence of correlation on the east side is attributed to the earlier start whereby time of starting is no longer an expression of the more obscure causal factor for increased height.

The inherent variability of seedling stocks although unquestionably existent, is too often invoked as the explanation of tree variability. It is significant in this experiment in which clonal stocks were used that the time of starting of the inserted buds varied and that the starting time on the west side is correlated with height of whip. Thus the behavior does not differ from that reported for seedling stocks and appears to eliminate inherent stock variability as a causal factor.

It has been indicated (1) that size of the seedling rootstock just prior to growth of the inserted bud is correlated with size of the yearling whip produced. The opinion was expressed that this relationship would hold regardless of whether the stocks were large as the result of inherent vigor or of environmental conditions. The relationship between caliper of stock and height of whip presented in Table II tends to substantiate this view, for in this case we are dealing with a variation in stock size within a clon.

TABLE II—THE SIZE OF CLONAL STOCKS IN RELATION TO RELATIVE START OF BUDS AND AVERAGE HEIGHT OF WHIPS

Caliper of Stock (Mms) (Spring 1932)	Number Trees	Relative Start of Buds	Average Height Whips (Fall 1932) (Ins.)
8.6— 9.5	52	$4.26 \pm .095$	$46.28 \pm .66$
9.6—10.5	102	$3.96 \pm .086$	$48.29 \pm .50$
10.6—11.5	171	$3.71 \pm .058$	$50.64 \pm .33$
11.6—12.5	109	$3.85 \pm .074$	$50.61 \pm .42$
12.6—13.5	50	$3.42 \pm .104$	$50.93 \pm .58$

The increases in height of whip shown for increased size of stock are of small practical significance and do not follow above the stock size interval of 10.6–11.5 mm. The coefficient of correlation obtained between stock size and height of whip of $+ .25 \pm .027$ is relatively small because of the fact that tree size increases with stock size only to a certain point beyond which further increases in stock size are without effect. Moreover, most of the stocks of this strong growing clon occur in the class intervals above those operative in effecting height of whip. The individuals falling in the extreme lower and upper class intervals have been omitted because of paucity of numbers.

Table II also discloses an inverse relationship between caliper of stock and relative time of bud start, the smaller stocks tending to be earliest in the start of the bud. It is somewhat anomalous that although small stocks tend to be associated with early bud start, and early bud start with large trees, yet large trees are not associated with small stocks, but with large stocks instead. Evidently the relationship between caliper of stock and height of whip is largely independent of the relationship with time of bud start. Substantiating this independence, the partial correlation between caliper and height, with time of starting held constant, is $+ .29$; — not appreciably different from the simple correlation of $+ .25$.

Although size of stock, in the lower size range, influences size of the nursery tree produced, it apparently is not the only factor operating for size. The more obscure factor, which is also correlated with starting time of the bud, is perhaps even more important. The nature of this factor still remains to be determined. It may be some condition of the bud or perhaps the nature of the union of bud and stock. The progress reported here indicates that early starting of the bud is only an accompanying and not a causal factor influencing the height of whip, and that it is not dependent upon any stock factor of inherent character.

Other studies are in progress in the hope of determining the nature of the various factors which possibly influence the variability of nursery trees.

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The Influence of Drying on the After-ripening and Germination of Fruit Tree Seeds

By I. C. Haut, *University of Maryland, College Park, Md.*

CERTAIN of the fruit-tree seeds are sown in large quantities each year by nurserymen, the resulting plants to be used as the understocks for horticultural varieties. The low soil temperature during the winter months provides the treatment by which the after-ripening processes are completed. The proper methods of handling the seed during this period of storage before it is sown in order that it may be in an optimum condition for after-ripening and thus assure a maximum germination, is of practical importance, and has received consideration by various investigators.

This paper presents data showing the effects of drying during the period of storage prior to after-ripening, and also following after-ripening, upon the subsequent germination in seeds of apple, peach, and Mazzard and Mahaleb cherry.

Drying the Seed Prior to After-ripening

Immediately upon harvesting, each kind of seed was divided into two lots. Lot I was allowed to become thoroughly dried at room temperature for 6 weeks, after which the seed was soaked for 5 days, placed in moist sand, and allowed to after-ripen in a low-temperature chamber at 1–2 degrees C. Lot II was immediately placed in moist sand, held at room temperature until Lot I had dried, and then placed in the low temperature chamber with the first lot. At regular intervals throughout the after-ripening period, germination tests were made. The seeds were sown in rows in flats containing sand and placed in a greenhouse. Eight 10-day intervals were used for the peach and Mazzard seeds; eight 7-day intervals for the apple seed; and six 14-day intervals for the Mahaleb. With the peach and Mazzard the endocarp was removed just prior to placing the seed in the flats since it was found in preliminary studies that the germination of a certain percentage of these seeds may be delayed or entirely prevented as a result of the mechanical resistance offered to the expanding embryos by the endocarp. The results are presented in Table I.

The observations here presented show no significant difference in germination between the lots dried and those held moist before the period of after-ripening. The rather low germination obtained in the tests with Mazzard and peach may in part be the result of the low after-ripening temperature employed, a temperature approximating 5 degrees C being considered more nearly the optimum for after-ripening in most seeds. Employment of the latter temperature, however, usually results in the occurrence of some germination while the seeds remain within the stratification medium. Since samples were taken at each of these intervals for further study

concerned with certain of the chemical changes occurring during the after-ripening period, the employment of higher temperatures would have in this case been undesirable.

TABLE I—INFLUENCE OF DRYING SEEDS PRIOR TO AFTER-RIPENING UPON SUBSEQUENT GERMINATION

Number Seed to Each Test	Lot Number	Treatment Previous to After-ripening	Per cent Germination When After-ripened at 1–2 Degrees C for Days Indicated								
			(Ck) 0	10	20	30	40	50	60	70	80
			Elberta Peach								
25	I	Dried	0	4	8	28	32	40	44	52	56
25	II	Moist	0	0	20	16	20	40	32	40	56
			Mazzard Cherry								
50	I	Dried	0	0	2	4	10	8	18	50	56
50	II	Moist	0	0	2	8	6	8	8	48	50

Number Seed to Each Test	Lot Number	Treatment Previous to After-ripening	Per cent Germination When After-ripened at 1–2 Degrees C for Days Indicated												
			(Ck) 0	7	14	21	28	35	42	49	56	63	70	77	84
			McIntosh Apple												
100	I	Dried	0	2	1	1	13	27	50	64	98				
100	II	Moist	0	3	11	29	44	43	68	75	90				
			Mahaleb Cherry												
100	I	Dried	0		3		12		41		52		71		81
100	II	Moist	0		2		10		36		41		65		84

DRYING FOLLOWING THE AFTER-RIPENING PERIOD

It has been found by a number of investigators that should the after-ripened embryos of certain seeds be placed under external conditions unfavorable for germination, they will after a time revert to a dormant condition, which in turn requires a second period of after-ripening, before germination can be secured.

Under field conditions, or during the handling of artificially after-ripened seeds before they are sown, the possibility exists that a certain loss in moisture may occur following after-ripening. Seeds may be permitted to dry somewhat before sowing to facilitate handling or may become partly dry from delay in sowing as the result of unfavorable weather conditions. The possible effect of this loss in moisture upon the induction of a second period of dormancy, is here considered.

For this study seeds of apple, Mazzard and Mahaleb were after-ripened at 1–2 degrees C. They were then removed from the stratification medium and allowed to dry at room temperature, for periods of 2, 5, 10, 15, 25, and 35 days. Upon the termination of each drying period seeds of the three kinds were soaked 48 hours

to restore the moisture content and the germination tests then conducted, as previously described. The results are reported in Table II.

TABLE II—EFFECT OF DRYING SEEDS FOLLOWING AFTER-RIPENING UPON SUBSEQUENT GERMINATION (EXPRESSED IN PER CENT)

Days After-ripened at 1–2 Degrees C		Seeds Dried for Days Indicated						
		(Ck) 0	2	5	10	15	25	35
		Mazzard Cherry						
90	Germination	94	21	8	1	0	0	0
	Moisture	39.8	17.9	4.8	4.4	3.9	4.1	4.0
		Mahaleb Cherry						
90	Germination	76	68	14	6	5	0	0
	Moisture	49.0	26.2	4.7	4.6	4.6	4.6	4.4
		McIntosh Apple						
63	Germination	99	86	70	46	37	21	6
	Moisture	40.9	15.4	9.0	7.9	6.2	5.8	5.5

Table II shows a marked reduction in germination to be associated with the drying of the seeds. A loss of germination approximating 78, 14, and 10 per cent for Mazzard, Mahaleb, and apple, respectively, resulted from 2 days of drying. After 5 days of drying a very large percentage of the after-ripened embryos of Mazzard and Mahaleb were incapable of germination; likewise in the apple after 25 days of drying. These findings are not in agreement with the statement of Crocker (1) that the after-ripened condition in Baldwin apple seed is retained even after 1 month in dry storage.

The results appear to have practical significance. Under conditions in the seed bed or in the field, a soil moisture deficiency in early spring when the seeds have become after-ripened and are prepared to germinate may result in this induced inability to grow. With artificially after-ripened seed, any treatment which permits the seed to partly or entirely dry prior to sowing, or following sowing, as for example, poor covering permitting exposure to a drying atmosphere or sowing in a dry soil, may result in reduced germination.

Sufficient seed of each kind was after-ripened and dried with the preceding lots so that a quantity remained following the 35-day interval of drying. Upon the completion of this period these were soaked for 48 hours, placed in moist sand at low temperature, and again after-ripened. Germination tests were made at six successive 10-day intervals with the Mazzard and Mahaleb, at 7, 15, 25, 35, 45, and 55 day intervals with the apple. The results obtained are given in Table III.

Only very low germination as indicated by the results in Table III was obtained following restratification. There were definite indications of injury to the seeds, becoming increasingly evident

as this second period of after-ripening progressed, until at the close only a very small percentage of seed was not noticeably injured. Apparently injury occurred during the drying period preceding this second after-ripening.

TABLE III—GERMINATION OF AFTER-RIPENED SEEDS DRIED AT ROOM TEMPERATURE FOR 35 DAYS, AND AGAIN AFTER-RIPENED

Days First After-ripened at 1–2 Degrees C	Germination (Per cent)	Days Dried	Germination Upon Second After-ripening at 1–2 Degrees C for Days Indicated (Per cent)												
			(Ck) 0	7	10	15	20	25	30	35	40	45	50	55	60
			Mazzard												
90	94	35	0	—	7	—	2	—	3	—	0	—	1	—	3
			Mahaleb												
90	76	35	0	—	9	—	3	—	1	—	1	—	3	—	0
			Apple												
63	99	35	6	19	—	17	—	16	—	15	—	11	—	13	—

It is well known that tissues dried too rapidly may be injured. Conceivably, drying at room temperature is sufficiently rapid to injure the embryos. Table II discloses, however, that after 2 days of exposure approximately 54, 46, and 38 per cent of the original moisture contents of the embryos were retained in Mahaleb, Mazzard, and apple, respectively. Not until after 5 days of drying did the moisture content of the seed become approximately constant. Therefore, the loss of moisture seems not to have been unduly rapid.

Furthermore, drying seed in a similar manner immediately following harvest and prior to after-ripening, has not proved detrimental to the embryos, and, in fact, is common practice with fruit-tree seeds. The embryos in a completely after-ripened condition are, therefore, apparently much more susceptible to injury from desiccation. Whether or not certain changes in the colloidal state of the protoplasm occur during after-ripening, permitting a greater or more rapid desiccation of the cells is as yet undetermined.

The results obtained upon restratifying again direct attention to the necessity for careful handling of after-ripened seed. This point may be important not only to those engaged in commercial propagation, but also to workers engaged in fruit breeding who often after-ripen seeds under controlled conditions in an effort to obtain a maximum germination. A complete germination is obviously desirable in breeding work.

Preliminary tests, upon which were based the experiments herein reported, have given essentially the same results.

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Catalase Activity in Relation to the After-Ripening of Fruit Tree Seeds

By I. C. Haut, *University of Maryland, College Park, Md.*

IN the seeds of most of the deciduous fruits a period of after-ripening subsequent to maturity is essential to germination. During this period the embryos presumably undergo certain processes upon the completion of which germination occurs, providing external conditions are favorable.

A quantitative study of some of the chemical and physiological changes occurring within the seeds of certain of the deciduous fruits during after-ripening has yielded, among others, the results herein presented on catalase activity.

Catalase activity has been used by numerous investigators as a measure of relative physiological activity in plant and animal tissue. The object of this study was to determine whether changes in catalase activity occur during after-ripening in seeds of some of the deciduous fruits, and to what extent these changes may be associated with growth releasal.

Four kinds of seed were used, namely, apple, peach, and Mazzard and Mahaleb cherries. Immediately upon harvesting, each kind of seed was divided into three lots and the following treatments given. Lot I was placed in moist sand and allowed to remain at room temperature (check lot). Lot II was placed in a low temperature chamber and allowed to after-ripen at 1–2 degrees C. The seed used in both Lot I and Lot II were not allowed to become dry prior to these treatments. Lot III was allowed to become thoroughly dried at room temperature, after which the seed was soaked for 5 days to re-establish the moisture content, placed in moist sand, and allowed to after-ripen at 1–2 degrees C.

At regular intervals throughout the after-ripening period seed was taken from each of these lots, and the structures enclosing the embryos removed. The embryos were then prepared for the catalase determinations. Eight 10-day intervals were used for the peach and Mazzard seeds; eight 7-day intervals for the apple seed; and six 14-day intervals for the Mahaleb seed. With each catalase determination a germination test was used as an indication of the progress of the after-ripening process. One hundred seeds each of apple and Mahaleb and 25 and 50 seeds, respectively, for peach and Mazzard were used for each germination test. The seeds were sown in rows in flats containing sand and placed in a greenhouse.

The material was prepared for the catalase determinations as follows. A definite weight of the sample was placed in a mortar together with an equal weight of $Ca\ CO_3$. One gram of sand and 5 cc of water were added and the tissue was macerated for 3 minutes. If the quantity of sand is not constant for each sample the same degree of fineness will not be obtained in a definite period of grind-

TABLE I—CATALASE ACTIVITY IN RELATION TO AFTER-RIPENING IN FRUIT TREE SEEDS

Days of Treatment	Seconds for Evolution of Oxygen in Quantities Indicated																Total Per cent Germination Lot II
	3 cc		5 cc		6 cc		7 cc		8 cc		9 cc		10 cc		12 cc		
	Temp.		Temp.		Temp.		Temp.		Temp.		Temp.		Temp.		Temp.		
	Room[1]	Low[2]	Room	Low	Room	Low	Room	Low	Room	Low	Room	Low	Room	Low	Room	Low	
	McIntosh Apple																
Check	28	—	45	—	54	—	68	—	82	—	97	—	121	—	170	—	0
7	32	29	47	46	56	57	71	66	84	82	102	92	128	122	175	164	3
14	29	28	45	44	56	54	67	65	82	81	95	97	118	113	162	157	11
21	30	27	47	42	58	50	69	61	86	75	98	90	125	103	173	150	29
28	28	22	45	39	54	50	62	57	80	70	97	81	120	93	168	146	44
35	31	22	48	38	59	49	66	55	82	66	97	76	123	89	164	138	43
42	29	20	46	35	55	45	68	53	82	62	95	71	119	85	169	131	68
49	28	19	45	32	54	43	66	48	80	57	95	61	116	78	162	115	75
56	30	15	47	29	57	35	66	44	83	52	96	54	121	70	164	97	90
	Elberta Peach																
Check	95	—	172	—	—	—	260	—	308	—	363	—	421	—	551	—	0
10	88	88	168	162	212	198	254	245	298	294	350	347	410	405	532	539	0
20	98	89	180	163	223	206	268	253	319	301	373	354	439	416	578	544	20
30	107	80	188	149	229	182	280	223	328	268	375	320	439	380	573	520	16
40	110	75	191	142	235	178	283	214	334	251	391	294	456	341	597	436	20
50	109	56	197	96	242	118	290	141	341	164	396	189	462	218	602	282	40
60	112	64	204	105	257	130	311	154	368	178	429	210	499	243	674	316	32
70	120	57	224	99	282	118	347	140	415	166	485	194	559	226	755	281	40
80	119	49	211	88	268	106	330	129	398	152	468	176	544	203	744	266	56

Mazzard Cherry

Check	51	—	88	—	113	—	134	—	163	—	189	—	219	—	296	—	0
10	56	*52*	92	*93*	114	*116*	138	*140*	164	*166*	195	*191*	231	*224*	321	*314*	0
20	53	*46*	86	*81*	110	*102*	132	*124*	159	*147*	187	*174*	218	*199*	281	*261*	2
30	54	*45*	89	*80*	105	*101*	135	*120*	158	*142*	194	*167*	226	*193*	286	*244*	8
40	55	*46*	84	*77*	104	*94*	130	*114*	153	*136*	184	*162*	221	*184*	304	*245*	6
50	57	*39*	87	*69*	106	*85*	137	*105*	158	*123*	195	*140*	225	*160*	303	*215*	8
60	52	*34*	91	*64*	111	*76*	134	*89*	156	*101*	185	*116*	220	*134*	287	*182*	8
70	55	*30*	97	*55*	115	*66*	150	*77*	186	*89*	210	*101*	244	*120*	327	*166*	48
80	59	*34*	101	*59*	128	*71*	157	*82*	187	*94*	224	*108*	262	*126*	362	*174*	50

Mahaleb Cherry

Check	31	—	57	—	70	—	87	—	101	—	125	—	153	—	224	—	0
14	31	*31*	57	*56*	73	*71*	90	*87*	104	*101*	124	*125*	153	*153*	226	*224*	2
28	29	*29*	58	*50*	71	*64*	88	*78*	102	*94*	122	*113*	153	*138*	220	*196*	10
42	30	*25*	61	*46*	73	*57*	95	*69*	108	*84*	138	*104*	162	*125*	232	*172*	36
56	32	*24*	60	*40*	73	*49*	96	*60*	107	*77*	130	*99*	160	*118*	227	*155*	41
70	31	*20*	60	*35*	76	*41*	96	*55*	110	*69*	131	*94*	163	*102*	231	*140*	65
84	29	*15*	58	*27*	70	*34*	89	*39*	100	*48*	122	*57*	151	*75*	221	*101*	84

[1]Lot I.
[2]Lot II.

ing. Where volumetric flasks are employed to obtain the desired dilution a volume error will also be introduced. One gram of tissue was used in each determination for Mazzard, apple and Mahaleb, and 2 grams for peach. Sufficient water was added to give final dilutions of 1–50 for Mazzard and Mahaleb, 1–100 for apple, and 1–25 for peach.

Immediately following dilution the catalase activity of the preparations were determined by means of an apparatus similar to that used by Knott (1) but modified to permit simultaneous shaking of duplicate samples. Five cc of the prepared solution and 5 cc of hydrogen peroxide were placed in the opposite arms of a Bunzel reaction tube. It is recognized that, with tissues low in activity, errors which may accrue during the sampling procedure may not be sufficiently magnified to become readily observable. However, with tissues high in catalase activity, a closely standardized procedure of sampling is necessary for a high degree of accuracy. Therefore, in the withdrawal of a sample aliquot, a standardized procedure, based on the results of preliminary studies, was used.

The bottle containing the sample was first thoroughly shaken and after 15 seconds standing 5 cc of the solution were withdrawn from the bottle at the rate of 1 cc per second. Sample bottles of the same size were used and the pipette was marked in such manner that it would be inserted to the same depth in the solution during the withdrawal of each sample.

The heavier material in the solution settles to the bottom rather quickly. It also settles out of the pipette. Preliminary studies indicated, therefore, that to obtain close checks between duplicate determinations, as well as to obtain results from one period to another which have been sampled on a comparable basis, it is essential that the length of time allowed for settling, the depth to which the pipette is inserted into the solution, and the time in which the solution is withdrawn into the pipette, are based upon a standardized procedure. The reaction tubes were connected with the burettes, and then submerged in the water bath which was maintained at 30 degrees C. Five minutes was allowed for the reaction tubes and their contents to come to equilibrium with the temperature of the bath. The reaction was then begun and the time seconds required to displace 3, 5, 6, 7, 8, 9, 10, and 12 cc of water, successively recorded with results reported in Table I. Lack of space precludes presentation of data on Lot III; these may be summarized in the statement that the changes in catalase activity were fundamentally like those in Lot II.

The results with each kind of seed indicate that as the after-ripening period progressed at the low temperature, distinct increases in catalase activity occurred. Furthermore, comparison of the percentage germination with the catalase activity at each interval in the low temperature treatment indicates a fairly close

association between increases in germination and increases in catalase activity.

No increases in catalase activity occurred at the corresponding intervals at room temperatures, and there was no germination. However, germination could not be expected since after-ripening does not occur at these temperatures.

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Relation Between Cion Top, Intermediate Stem Piece, and Rootstock on the Growth and Configuration of Topworked Apple Trees

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ABSTRACT

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BENCH grafts have been made between various standard varieties of apple trees and various seedling and clonal rootstocks. In addition, pieces of stem from various varieties and clonal lines have been introduced between the variety top and the rootstock, thus making double-worked trees. The trees resulting from these grafts show various effects of rootstock, intermediate stem piece, and cion top upon growth and configuration of both root and top. In most instances the root system has been governed in development by the cion top rather than by the intermediate stem piece. On the other hand, in the case of a dwarfing stock, the dwarfing effect has been dominant whether the dwarfing portion has been either cion, intermediate stem piece, or root,—always resulting in a dwarf tree. The facts indicate the presence of more than one general factor in the effect of stock upon cion and cion upon stock. In one case it may be the vigor of the root system that is dominant, in another case it may be the vigor and type of the cion top, while in a third case it may be the compatibility between the tissues united in the graft.

The Exosmosis Method of Determining Injury, as Applied to Apple Rootstock Hardiness Studies

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DEXTER, Tottingham, and Graber (1, 2) have called attention to the use of the exosmosis method of measuring the cold resistance of cereal and forage plants. This method is based upon the assumption that the release of electrolytes by the cell, measured by electrical conductivity procedure, constitutes a direct reading of the amount of injury inflicted by a given treatment. This assumption of course needs to be checked carefully for each class of material. Almost all their studies were concerned with relatively hard material—plants which are not injured by cold unless ice crystals actually form.

The present paper reports the use of this procedure in the selection of cold-resistant fruit-tree stocks, and considers some of the limitations and uses of the method in such studies. Our investigations along these lines have as their immediate objective the determination of relative hardiness of previous clonal rootstock selections and the isolation of particularly resistant individuals from seedlings as a basis for future clonal development and perhaps also for seed selection. We are interested in the whole problem of hardiness, however, and are using the exosmosis method for throwing new light on the old problem of stock and scion relationships, especially as regards effect on hardiness.

As used in the rootstock work the method was essentially as follows: Samples of roots were taken from trees in the field or in storage, cut into half-inch lengths, quickly washed, rinsed in distilled water, and the surface water dried off. Next the material was weighed out into comparable samples. These were placed in 75 cc test tubes, and stoppers inserted. The cold treatment in this case consisted merely of placing the sample tubes in a room maintained at a temperature close to, or below, the killing point. Following removal from the cold, 50 cc of distilled water at 32 degrees F. was poured on each sample and the tube restoppered and left overnight in the ice box in water containing melting ice. This latter detail was followed merely because it provided a simple method for keeping all material at a fairly constant temperature. ~~With certain plant material other than apple, injury to the checks may follow this treatment, due to the low temperature or the deficiency of oxygen.~~ Whenever convenient, after from 12 to 36 hours, the liquid from each sample tube, still maintained at 32 degrees, was tested for its electrical conductivity.

A careful check of the exosmosis method was made against the "freeze and wait" visual method of determining injury. For the test referred to in Table I, roots from 1-year root cuttings of U..S. D. A. apple clon 316 Vermont which had been in the storage cellar for 3 weeks were used. As brought out in the table, complete agreement in

results was obtained between the conductivity readings and the observations made after the material had remained in sand at about 60 degrees F for 7 days, the conductivity readings giving much the more sensitive figures for the intermediate degrees of injury.

TABLE I—Comparison Between Conductivity Readings and Results of Planting Tests of Comparably-treated Material. Clon 316 Vermont. One-year Apple Roots

Treatment	Conductivity Test		Planting Test
	Equiv. Cond. (Reciprocal Ohms)	Estimate of Condition	Observed Condition After 7 Days
Check	29,310	Satisfactory	Callused
Hours held frozen at 15° F			
¼	26,144	Satisfactory	Callused
½	21,400	Satisfactory	Callused
¾	9,670	Slight injury	Callused
1	6,865	Slight injury	Large roots callused, small roots killed
2	2,362	Badly injured	No callus; almost dead
3	2,170	Probably killed	Surely killed
4	2,180	Probably killed	Surely killed
5	2,041	Probably killed	Surely killed
24	1,642	Surely killed	Surely killed
Hours held dry at 70° F			
1	15,050	Satisfactory	Callused
1¼	18,480	Satisfactory	Callused
1½	16,210	Satisfactory	Callused
1¾	16,670	Satisfactory	Callused
2¾	12,560	Satisfactory	Callused
3¾	12,150	Satisfactory	Callused
4¾	8,460	Slight injury	Callused
5¾	9,965	Slight injury	Callused
24	2,922	Badly injured	Slight callus; badly injured

The time of exposure of the test material to a killing temperature is, of course, particularly important. The length of the subsequent period of exosmosis, however, is relatively unimportant. No matter what the degree of injury, any plant material placed in distilled water can be expected to show some outward movement of electrolytes. The greater the injury the faster will be this movement. Apple root samples that had been subjected to different degrees of injury all showed progressively greater conductivity over a period of 4 days, but relative readings remained the same. This implies very great leeway in conductivity readings, provided all material in any given series is allowed the same time period for exosmosis.

One objection, or rather question, in many minds regarding the exosmosis method concerns the cut surface area. It is natural to suppose that the amount of exosmosis is proportional to the cut surface; however, we must remember that we are dealing with solute-loss rather than water evaporation, and a cut surface exposes only an extremely small fraction of the total number of cells. Virtually, only

the cells mechanically ruptured are involved in electrolyte loss in unfrozen tissue. With death or severe injury, as by cold, every cell gives up electrolytes in proportion to the injury suffered, with relatively little regard to the surface relations.

Of course, size of tissue cannot be wholly ignored, for in general, the smaller the diameter, the greater the proportion of living cells, and hence, to that extent, the greater the injury at a given critical temperature.

In these studies a Hall-Adams, radio type conductivity outfit, with a platinum electrode, was used for the conductivity determinations. It is believed that for this kind of work almost any type of conductivity outfit commonly used in plant physiology laboratories could be employed.

The preparation and treatment given the test material constitutes the time-consuming end of these tests. The time required to make the reading is usually only a few seconds. In all cases, however, it is advisable to wait a few seconds and take a second reading, for sometimes a difference in CO_2 content of the closed test tube leads to a considerable change in resistance, during a minute or more. In such instances the final reading, made after virtual equilibrium has been reached, should be accepted.

Samples of almost any size could be used. The exosmosis from a few milligrams of material could be accurately measured, but unless one were interested only in a restricted tissue a large composite sample should be used, chiefly due to the known variability in resistance of the various tissues and the different portions of the same plant, particularly with roots. If we want to know the exact reaction of a few cubic millimeters of tissue, this method will give it; but for most hardiness studies it is more of an average that is desired, hence the necessity for larger samples.

Of course whatever the weighing error, it will be directly reflected in the conductivity readings. Likewise differences in water content of similar samples will appear in the final reading, due not so much to slight differences in the amount of water itself as to differences in the absolute amount of dry material weighed into the sample. Usually from 5 to 20 grams of material were used in these apple root studies.

It is of course true that cold resistance is a complex problem and many factors besides the inherent make-up of a plant are of cardinal importance in determining injury at a given time. In one sense it can be said that the immediate environment is of far more importance than the genetic constitution in determining resistance. That is, under one set of commonly found conditions, the hardiest plant becomes more susceptible than the tenderest under other conditions. This has been observed in many cases with apple clons, especially with roots of trees 3 to 5 years old. Both by the "freeze and wait" visual method, and by the exosmosis method, a considerable range in hardiness has been observed between different root portions of the same individual plant. Hence in sampling for the determination of genetically hardy clons, it is important to use enough material to get an average. On the other hand, with stems, the difference in hardi-

ness between different portions of the same year's growth is generally very much less. Consequently, here less material is required for a representative sample.

Of course many other points will become evident to the investigator working with some particular phase of cold injury. The point emphasized here is that whatever the problems involved in cold injury to horticultural material, the exosmosis method should certainly be looked on as a very useful tool.

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The Identification of Mazzard and Mahaleb Cherry Stocks

By T. E. RAWLINS and K. H. JARVIS, *University of California, Berkeley, Calif.*

WHILE studying the influence of cherry stocks on disease resistance the authors needed a simple and reliable method for determining whether trees were on Mazzard or Mahaleb stocks. A number of growers have also requested such a method.

After trying the methods described by Nebel (1), Tukey (2), and Upshall (3) for identifying these stocks, and doing experimental work in an attempt to improve these methods, we have found the following simple technic to be most satisfactory: Small pieces of bark are cut from below the union and, with the aid of a brush, are washed in water for a few seconds to remove the adhering soil. The bark is then cut into thin splinters which are placed in a glass tumbler containing enough clean water to cover them. After 2 to 5 minutes, water containing Mazzard bark assumes a yellow to orange color while that containing Mahaleb remains colorless. This method of identification was tried on 15 Mazzard and 15 Mahaleb stocks and found to satisfactorily distinguish the two species in every case.

The Morello stock behaves similarly to the Mazzard when subjected to this treatment. Since the Morello stock is used extensively only in the Stockton District of California, growers in other cherry districts seldom need a method of distinguishing this stock from Mazzard or Mahaleb.

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An Apparatus and Method for Determining Bound Water in Plant Tissue[1]

By Arvil L. Stark, *Iowa State College, Ames, Ia.*

THE term *bound water* as generally applied in biology refers to water held against some extracting force. Extraction forces such as mechanical pressure (hydraulic press), and withdrawal by

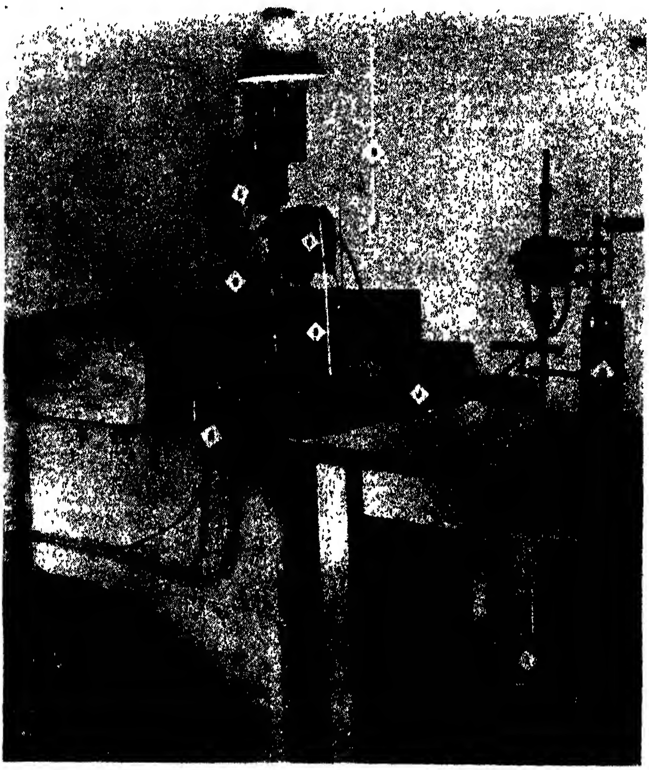

Fig. 1. Photograph of apparatus. A, tubes joining coil and compressor; B, wire from relay to heating unit; C, relay; D, mercury thermo-regulator; E, motor to stir bath; G. thermos botle; H, thermometer for room temperature readings; I, thermos jug; J, suction tube for pipette filling:

freezing remove only the *free water*, making possible the calculation of bound water by the subtraction of free water from the total quantity present as determined by oven drying. A review of the related literature indicates the importance of bound water in hardiness and drouth resistant studies.

[1]Journal Paper No. B89 of the Iowa Agricultural Experiment Station, Ames, Ia. Project 270.

In a study of winter hardiness of apple shoots by the Pomology Subsection of Iowa State College the following apparatus has been developed and used with the heat-of-fusion or calorimetric method for measuring bound water.

The material is frozen in an insulated metal box holding about 52 liters of calcium chloride brine. Cooling is accomplished by means of a mechanical refrigeration unit. A constant temperature within 0.1 degree C is maintained in the brine by a supersensitive dry cell relay thermo-regulator with two knife type heaters (Fig 1, BCD). The bath is cooled continuously and heated to the desired temperature by the termo-regulator. A simple six-bladed propeller is used to circulate the brine. Pyrex test tubes 25 by 250mm containing the samples to be frozen are held in place in the cooling brine by elastic bands stretched across a perforated board lid. A thermometer is placed in the tube containing the last sample to be run. As each sample is taken its temperature is recorded as that indicated by the thermometer in this tube.

When making a determination, 200 ml of water are first pipetted into an ordinary wide mouth thermos bottle equipped with a thermometer and a stirring device. While the water is being stirred the temperature of the frozen sample is recorded. Then the temperature of the water is recorded, followed by the quick transfer of the frozen sample to the water in the thermos bottle. The interval of transfer should be as short as possible, with minimum splashing of the water to the walls of the bottle. Stirring of the water and the sample should continue until the final low point is reached, when the second temperature of the water is read.

After the final temperature reading is made the sample is put in a weighing bottle for dry weight determination. The water content is determined as the difference between the fresh weight and the dry weight of the sample after being held 60 hours at 80 degrees C under a vacuum of approximately 760 mm of mercury.

The free water in the frozen sample is calculated by the following formula taken from Thoenes (4) and modified by Robinson (1).

$$\text{Free water} = \frac{FN(T_3 - T_4) - SW(T_2 + T_4)}{80 - \frac{T_2}{2}}$$

In which:

- F = factor for apparatus.
- N = volume in ml of water in bottle.
- T_3 = initial temperature, degrees centrigrade, of water in bottle.
- T_4 = final temperature of water after sample is added.
- T_2 = temperature of frozen sample.
- S = specific heat of sample.
- W = fresh weight of sample in grams.
- 80 = calories to convert one gram of ice to water at same temperature.
- 2 accounts for specific heat of ice.

Example: Free water =

$$\frac{200 \times 1.070 \times (25.00 - 21.00) - 0.700 \times 20.000 \times (20.00 + 21.00)}{80 - \frac{20.00}{2}}$$

= 4.03 gms. free water.

To this quantity is added the water that collected on the walls of the test tube during freezing of the sample. It is determined by weighing the tube before and after evaporating the water.

The specific heat of a sample is determined from its duplicate by cooling to 1 degree C above zero and following the same procedure as described for free water determination. The usual method employed in physics for calculating specific heats is followed. By a series of determinations it has been shown (3) that specific heat is correlated with the percentage of water in apple shoots, and figures for this value may be taken from a graph in which specific heat is plotted against the percentage of water in the shoots.

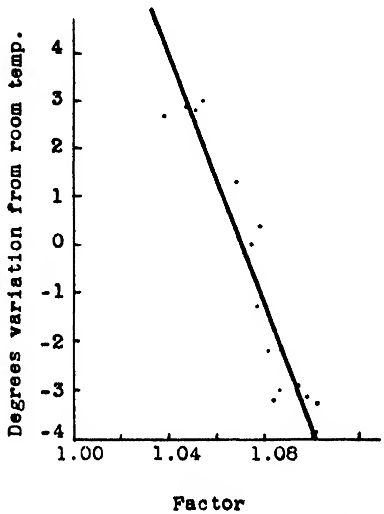

FIG. 2. Relation of factor to variation from room temperature of mid-point of temperature change in bottle.

Robinson (1) is responsible for the introduction of the factor "F" in the formula, which is merely the thermal capacity or water equivalent of the apparatus. It is obvious that this factor would vary with a change of water level in the bottle.

If the mid-point of the temperature change in the bottle is not at room temperature another correction is necessary. This, with the thermal capacity of the bottle, is made in the following manner.

Six grams of water are weighed in each of several small glass vials, which are immediately stoppered. After the water is frozen the stoppers are removed 30 minutes previous to making the determination. Each of these vials is run just as a shoot sample, except enough additional water is added to bring the level in the thermos bottle up to 220 ml, the same level as when shoot samples are used. This eliminates the correction necessary for change in water level.

In order to find the correction for variation of the mid-point from room temperature, several trials are made with the temperature of the water in the bottle above and below room temperature. Corrections for the apparatus used in this study are shown in Fig. 2.

This graph indicates results from a definite apparatus with a constant water level and is not usable with any other apparatus or

water level. The thermal capacity of the apparatus is included in this correction. The following illustration is given to show how the factor is obtained.

$$NX=(Wx0.5xT_2) + (80xW) + W(T_3-X) + VS(T_2+T_4)$$

In which:

X = calculated temperature change.
N = volume in ml of water in bottle.
W = weight of water frozen.
0.5 = specific heat of ice.
80 = calories to convert one gram of ice to water at same temperature.
T_2 = temperature of frozen ice.
T_3 = initial temperature of water in bottle.
T_4 = final temperature of water after sample is added.
V = weight of glass vial in grams.
S = specific heat of glass.

In the example given below 3.00 is the actual temperature change in the vial as determined by the thermometer. This is divided into the calculated temperature change to give the factor.

Example:

$$212X = (6.000x0.5x5.00) + (80x6.000)+6.000(25.00-X) + (5.000x0.161x27.00)$$

$$218X = 666.73$$

$$X = \frac{3.06}{3.00} = 1.02 \text{ factor}$$

If the formula for free water is compared with that given by Robinson (1), it will be seen that the freezing point of the tissue is not shown here. This value decreases as the tissue thaws, since ice formation in the tissue increases with temperature lowering. Robinson (2) has now dropped this value from his calculations.

Thermometers graduated to tenth degrees are used in this study, but for greater accuracy necessary with smaller quantities of material a thermocouple could be used.

Stirring of the water in the bottle is accomplished by means of a small propeller and a variable speed motor. A satisfactory propeller may be made from a circular sheet of copper about 25 mm in diameter. Four cuts are made on four radii 90 degrees apart so that the cut extends almost to the center and nearly to the outer edge. Joining the outer end of the radial cuts four additional cuts are made parallel to the circumference of the copper plate. By pushing upward the vertices of the parts freed by the cuts and fastening a shaft in the center a propeller will be formed that eliminates interference from the material, which is important in order to prevent breaking the thin walls of the thermos bottle.

This propeller is fastened in a large rubber stopper that is fitted in the mouth of the thermos bottle. An elastic band is used as a belt for joining the propeller pulley with the stirring motor. In the same stopper is inserted the thermometer parallel to the shaft of the propeller.

It is convenient to use a suction pump to fill the 200 ml pipette and a large thermos jug to hold the water used in the determinations. Thermometer lenses to increase the accuracy of temperature readings are desirable.

Robinson (2) suggests a constant temperature water bath to keep the thermos bottle at a desired temperature, but with large quantities of material this refinement is hardly necessary since room temperature is quite constant.

With a freezing time of 4 hours and by putting the samples in the cooling brine as weighed, it is possible with this procedure to determine about 45 samples in a day.

The accuracy varies with the range of temperature change of the water in the bottle, the greater the change the smaller the percentage error. With the thermometers used, a difference of 5 degrees C between the initial and final temperature in the bottle will give a value accurate to approximately 1 per cent error.

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The Effect of Certain Spray Materials on the Carbon Dioxide Assimilation by McIntosh Apple Leaves

By M. B. Hoffman, *Cornell University, Ithaca, N. Y.*

IN commercial fruit production, insect and fungus control requires the use of sprays. Under certain conditions, the spray materials may cause visible injury to the foliage. Dutton (1), Hedrick (2). The possibility of fungicides or insecticides causing a reduction in the efficiency of foliage which does not express itself in visible injury has been suggested from time to time, but the literature contains little data on this phase of the problem. Spuler, Overley and Green (5). This may be due to the lack of a method for measuring leaf efficiency under conditions required to carry out such experimentation.

Methods and Materials

Heinicke and Hoffman (4) have recently described an apparatus for the measurement of CO_2 assimilated by leaves under natural conditions. The procedure was the same as described by Heinicke (3) except that the assimilating chambers were of the cellophane envelope type. Essentially, the principle of this method is that the assimilating leaf is confined in a closely fitting chamber which provides nearly normal conditions with respect to light and temperature, and through which a constant stream of air is drawn. After leaving the assimilation chamber, the air passes through absorption towers in which the carbon dioxide is removed. The amount absorbed is determined by titration. By having an extra tower drawing only upon the atmosphere, the concentration of the carbon dioxide in the surrounding air is found and the amount absorbed by the plant material is at once calculated by difference. Numerous precautions and careful technique are required if accurate results are to be obtained.

In preliminary studies on the amount of carbon dioxide assimilated by apple leaves, it was found that the rate of photosynthesis of a given leaf will vary at different times of the day and large variations might occur from day to day, showing some correlation with environmental conditions, namely, sunlight, water supply, etc. Moreover, two leaves of about equal size and appearance, located in the same section of a given shoot, may show an appreciable difference in the rate of assimilation even though both are tested at the same time under apparently similar external conditions. In view of this fact it is desirable to determine the rate of carbon dioxide assimilation of a given leaf as compared to that of a neighboring leaf before any treatment is given.

One-year-old McIntosh whips, about 40 inches high, growing in 10-inch pots, were used in the treatments. Some of these trees showed lighter green leaves than others, due to soil conditions.

All the trees were growing in the greenhouse. The usual practice followed was to select a pair of uniform leaves, on each of two trees, and determine the rate of assimilation for a period of exactly 4 hours, starting about 8 a. m. After this preliminary test, one leaf of each pair was immediately treated with some spray material and beginning next day, the rate of assimilation of these same leaves was determined for several successive days. Usually, when a series of determinations was started, one pair of leaves was selected having light green foliage, and another pair on a tree with darker foliage.

In all the work that has been carried out with lime-sulphur, the regular summer strength (2½ gallons of commercial lime-sulphur in 100 gallons of water) was used. The effect of combinations with lime-sulphur, such as lead arsenate or excess lime, and other spray materials are also being studied and will be reported at a later date.

Results with Lime-Sulphur

During the summer of 1932, over 100 determinations of photosynthetic activity were made on the effect of lime-sulphur on McIntosh apple leaves. The results of these determinations are averaged in Table I.

TABLE I—Average Assimilation of Sprayed and Unsprayed Foliage

Treatment Schedule	CO_2 Assimilation			
	Mg4Hrs.100Cm.^{2}		Ratio 100a/b	Reduction due to Treatment
	(b) Before Treatment	(a) After Treatment		
Unsprayed	38.7	43.3	112	
L-S Spray	40.8	28.7	70	37%

This table shows that the slight difference in efficiency of leaves prior to treatment was in favor of the group to be treated. It will be noticed that the untreated leaves used slightly more carbon dioxide after treatment than in the trial determinations. Weather conditions more favorable to photosynthesis will account for this difference. The sprayed leaves show a reduction of 37.1 per cent of their former activity.

The method of obtaining these data, i.e., from paired leaves, presents a suitable opportunity for statistical interpretation by Students' method. When the odds are calculated for single determinations they are found to be greater than 9999:1, that the above difference is significant.

The amount of reduction in the activity of leaves, due to lime-sulphur spray varies considerably. It will depend somewhat on the weather, but more on the internal condition of the leaf itself. The following representative data will serve to illustrate this point.

TABLE II—EFFECT OF 1–40 LIME-SULPHUR ON CO_2 ASSIMILATION BY APPLE LEAVES

Tree and Leaf	Mg. CO_2 Assimilated per 100 Sq. Cm. Leaf Surface During a 4-Hr. Run	Treatment	CO_2 Assimilated per 100 Sq. Cm. Leaf Surface. Expressed in Per cent of Assimilation Before Treatment — Date of Determination			
	A.M. July 14	P.M. July 14	A.M. July 15	A.M. July 16	P.M. July 28	A.M. July 29
I 5	15.2	Untr.	89.1	91.0		
I 8	24.6	Sp.L-S	3.0	25.3	-	
P 28	47.5	Untr.	105.9	110.8	111.2	103.2
P 24	47.6	Sp.L-S	96.6	86.2	93.0	81.1
Temp: Min.	26°C		24°C	23°C	30°C	22°C
Max.	32°C		27°C	31°C	31°C	25°C
Weather:	Bright sun		Sun hazy	Bright sun hazy	Little sun cloudy	Little sun cloudy

In Table II, tree "I" was a plant with light green foliage. Tree "P" was more vigorous with dark green foliage. The numbers in the left hand column indicate the leaf number, counting from the base of the current year's shoot growth. The data in the second column indicate what the leaves are capable of assimilating under a set of environmental conditions which existed at the time of the determination and which were presumably the same for all leaves. The third column indicates the treatment given after the trial run. Leaf 8 on tree "I" was sprayed with lime-sulphur and leaf 5 remained untreated for later comparison. Similarly, leaf 24 on tree "P" was sprayed with lime-sulphur and leaf 28 left normal. The remaining columns are the results of tests after treatment. The value obtained in the trial run is regarded as 100. In the case of the normal leaves, which remain untreated, any deviation from 100 is assumed to be due to a change in environmental conditions that affect photosynthesis; while with the sprayed leaves, a deviation would involve the treatment as well as the change in light, temperature, etc.

The first point of interest in Table II is that the light green leaves have removed less than one-half as much CO_2 from the air stream as the dark green leaves. This is characteristic of many determinations. The first day after treatment, the efficiency of the sprayed light green leaf drops down to 3.0 per cent of its former value. The second day after treatment, the sprayed leaf I-8 has apparently recovered from some of the ill effects of treatment; however, it still shows a 65 per cent reduction in carbon dioxide utilization as compared with I-5.

The sprayed dark green leaf P-24, compared with the untreated green leaf P-28, shows a slight reduction in efficiency of 9.3 and 24.6 per cent for the first and second days, respectively, after treatment.

It should be noted that the injury, though appreciable, is less than on the light green leaves.

It would be of interest to know how long this ill effect of lime-sulphur persists. The last two columns in Table II are determinations made 14 and 15 days, respectively, after the treatment on July 14. Apparently, there is as much reduction in the rate of assimilation of the sprayed leaf 2 weeks after treatment as there was on the second day after spraying. Even though the harmful effects of lime-sulphur on the assimilation of apple leaves disappeared completely 2 weeks after application, they may, nevertheless, be of much practical significance. Lime-sulphur is generally used as an early season spray in preference to other fungicides, and at this period there is a heavy demand for organic food supply of the tree for the rapidly developing flowers and fruits. Any reduction in leaf efficiency at this time may have a marked influence on such characteristics as setting of fruit, biennial bearing, etc.

TABLE III—EFFECT OF 1–40 LIME-SULPHUR ON CO_2 ASSIMILATION BY APPLE LEAVES

Tree and Leaf	Mg. CO_2 Assimilated per 100 Sq. Cm. Leaf Surface During a 4-Hr. Run	Treatment	CO_2 Assimilated per 100 Sq. Cm. Leaf Surface Expressed in Per cent of Assimilation Before Treatment — Date of Determination	
	A.M. Aug. 20	P.M. Aug. 21	A.M. Aug. 22	A.M. Aug. 27
U 12	34.8	Untr.	108.8	108.6
U 14	47.5	Sp.L-S	70.3	63.9
V 29	75.5	Untr.	93.8	74.3
V 27	61.0	Sp.L-S	77.5	75.5
Temp:				
Min.	26°C		26°C	27°C
Max.	30°C		29°C	31°C
Weather:	Bright sun		Bright sun	Sun intermittent Cloudiness

None of the results reported above on the effect of lime-sulphur were accompanied by visible injury, such as tip or marginal burning. The treated leaves appeared perfectly normal except for the slight deposit left by the spray after drying. In some experiments, however, visible injury did occur to a sprayed leaf when the temperature was exceptionally high. In these cases the air stream was actually enriched with carbon dioxide, indicating that during the formation of this visible injury respiration had exceeded photosynthesis. It may be of interest to note that the light green leaves, both sprayed and unsprayed, were more subject to injury from high temperatures than the dark green leaves.

Table III shows the results of another series of determinations. Plant "U" was a tree with light green foliage, and plant "V" a vigorous tree with dark green foliage. When compared with the

normal light green leaf U-12, leaf U-14 shows a reduction of 38.5 per cent in its ability to remove CO_2 from the air stream on the day following spraying. One week after treatment (August 27) this reduction amounts to 44.7 per cent. In the case of the green leaves on plant "V", the sprayed leaf V-27 shows a reduction of 16.3 per cent as compared with the normal leaf the first day following treatment; while one week later the depressing effect of lime-sulphur has apparently disappeared. However, it will be noticed that the weather was mostly cloudy with little sun during the determination. This may have tended to either decrease the efficiency of the normal leaf V-29, or to increase the efficiency of the sprayed leaf V-27.

Results with Other Sprays

Several series of experiments have been carried out, using standard Bordeaux mixture, in a way similar to that described for lime-sulphur. This material sometimes caused a slight reduction in the amount of CO_2 removed from the air stream, while at other times no reduction could be detected. When a slight reduction occurs in leaf efficiency, this is probably due to some physical effect of the Bordeaux precipitate on the leaf, rather than to a chemical disturbance of the photosynthetic mechanism which seems to take place with a material like lime-sulphur. The fact that the leaves tend to regain their former efficiency when the Bordeaux precipitate is washed from them, after several determinations have shown a slight decrease in CO_2 utilization, lends support to this view.

Two series of tests, using a commercial brand of summer oil, have shown an immediate and appreciable reduction in the amount of carbon dioxide taken up by the sprayed leaves However, determinations lasting over a week or more show a consistent and almost complete recovery of the treated leaves.

Acknowledgment

Dr. A. J. Heinicke suggested this problem and he has given much valuable aid in all phases of the work.

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Influence of Commercial Fertilizers on Yields, Grades, and Value of Potatoes in Hood River Valley

By Gordon G. Brown, *Oregon Experiment Station, Hood River. Ore.*

THE following is a partial report of coöperative fertilizer experimental work with Russet Burbank potatoes under irrigated conditions from 1920 to 1930, inclusive. The purpose of the tests was to determine the most effective and economical amounts of nitrogen (N), phosphoric acid (P), and potash (K) when used alone or in various combinations. Materials used were ammonium sulphate, nitrate of soda, urea, dried blood, superphosphate, treble phosphate, and sulphate and muriate of potash. The rate of plant-food applications was based upon the per cent by weight of water soluble or citrate soluble elements contained within the several carriers indicated. The greatest combined weight of N and P was 511 pounds per acre and the least, 137 pounds. The former was applied as 800 pounds ammonium sulphate and 2000 pounds superphosphate; the latter as 140 and 500 pounds of the same materials, respectively. The weight of N used, to which a value of 1 is assigned, was combined with P in ratios varying from 1–1 to 1–3.7. Since the total amount used, however, rather than the ratio, appears to be the more significant factor, yields and grades are correlated with the former.

Parkdale loam, on which all tests were conducted is well adapted to the production of Russet Burbank and other late varieties. The soil, of glacial origin, at an elevation of 1700 feet, is a uniform, loose, friable, yellowish-brown loam. Its moisture holding capacity is good; its reaction, neutral; its mineral elements, variable. Limiting soil elements are phosphorus and sulphur and, to some extent, nitrogen and calcium.

During the period of experimentation 20 separate tests were conducted, all of which were under green-manure soil conditions. Within these tests 55 individual N-P plots were included. One or two check plots were used in each experiment. Fertilizer plots, averaging 1/40 acre in size were in duplicate and repeated in parallel tests. The average yield from the checks was used as a basis for determining increases in yield or per cent in fertilized plots.

N-P plots were grouped upon the basis of the average total amount of plant-food applied per acre as follows: Group 1 (11 plots), 113 pounds; Group 2 (31 plots), 239 pounds; Group 3 (6 plots), 377 pounds; and Group 4 (7 plots), 507 pounds. Yields, grades, and costs are shown in Tables I and II. Results are discussed in later paragraphs. Yields and grades on N–P–K plots are reported here in part only.

Results of preliminary experiments indicated that the most economical use of fertilizer was made where green manure crops were

grown or where barnyard manure was applied. Hubam and biennial white sweet clover, alfalfa, and red and crimson clover were used in 3- or 4-year rotations previous to potato planting on all experimental plots including checks.

Average yields of unfertilized Russet Burbank potatoes grown after turning under vetch-hubam, alsike, alfalfa, and biennial white sweet clover are high and differ but slightly, being 244, 241, 229 and 235 sacks (100 pounds each) per acre; with red clover the yield was only 166 sacks. Without green manure, unfertilized plots yielded less than 100 sacks. The superiority of alfalfa or sweet clover over red clover as green manure crops for potatoes is indicated throughout a wide range in amounts of fertilizer used. Thus, with alfalfa the number of sacks per 100 pounds of N-P applied when used in the amount of 124, 245, 346, and 504 pounds per acre was 221, 144, 106, and 75 sacks; and with red clover, 163, 107, 59.4, and (4th value not represented).

TABLE I—Yields of Russet Burbank Potatoes per Acre and Increases over Unfertilized Plots

Group No.	Plant Food Applied per Acre (Pounds)		Yield (Sacks per Acre)		Increase over the Checks			
					Sacks		Per cent	
	N	P_2O_5	Fertilized Plots	Checks	Total	Per 100 Pounds Plant Food Applied	Total	Per 100 Pounds Plant Food Applied
1	34	79	256	188	68	60.2	36.2	32.0
2	79	160	291	181	110	46.0	60.7	25.4
3	118	259	366	195	171	45.3	87.9	23.3
4	173	334	322	157	165	32.5	105.1	20.7

Results of the first experiments with Russet Burbank indicated that N–P or N–P–K fertilizers are most effective and economical. Those containing only one plant-food element failed to produce profitable increases over unfertilized plots and, with some applications of potash alone, a net loss resulted. These results were uniformly obtained in experiments where several green manure crops were grown and other varieties of potatoes were used.

The production of Russet Burbank on fall plowed, 3-year alfalfa sod is of interest in relation to the use of varying amounts of ammonium sulphate and superphosphate. The initial application was 100 pounds per acre of ammonium sulphate and 250 pounds of superphosphate. Amounts used in the seven adjacent plots were progressively increased by multiples of 2, 3, 4, 5, 6, 7, and 8 respectively. The N–P ratio was 1 to 2.7 and the weight of plant-food applied varied from 63 to 504 pounds per acre contained in total fertilizer applications of 350 to 2800 pounds. Plots were subdivided, one area being planted to 3 ounces whole seed and the other to 1½ ounces cut seed representing equal halves of whole seed of similar character. Total yield responses of fertilizer appli-

cations in this experiment reveal a very striking and fairly consistent upward trend until 378 pounds plant food (supplied by 600 pounds ammonium sulphate and 1500 pounds superphosphate) were applied for whole seed. Thereafter, the trend in yield is inconsistent. Yields per acre, from checks and from lower and higher fertilizer applications, respectively, were whole seed, 207, 306, and 407 sacks; and cut seed 184, 217, and 351 sacks. Yields per 100-pound unit of applied plant-food varied in reverse order to total yields. For whole seed the range is from 485 to 80 sacks, and for cut seed from 345 to 69 sacks. Fertilizer costs per acre vary from $6.52 to $52.16. From the 504-, 378-, 252-, and 63-pound applications which gave increases of 202, 195, 150, and 105 sacks per acre the respective costs per sack were $0.258, $0.20, $0.173, and $0.062. The effect of the law of diminishing returns from increasing fertilizer expenditure is shown in the above data.

TABLE II—FERTILIZER TREATMENT COSTS AND NET VALUES

Group No.	Plant Food Applied per Acre (Pounds)		Cost of Fertilizer (Dollars)			Net Value of Increased Yield per Acre Based on Gross Value per Sack in Dollars		
	N	P_2O_5	Per Acre	Per Sack	Per Sack Increase	0.75	1.00	1.25
1	34	79	11.34	.044	.167	39.66	56.66	73.66
2	79	160	24.71	.085	.225	57.75	85.29	112.79
3	118	259	38.57	.105	.225	90.05	132.4	175.80
4	173	334	52.48	.163	.318	71.27	112.52	153.77

TABLE III—YIELDS AND GRADES OF RUSSET BURBANK WITH SULFUR AND NON-SULFUR CARRYING FERTILIZERS[1]

Series	Yields per Acre and Grades					Increase Over Unfertilized Plots			
	Total Sacks	No. 1		No. 2		Sacks			
		Sacks	Per cent	Sacks	Per cent	Total	No. 1	No. 2	Total Per ct.
1. No sulfur	346	264	76	62.7	18	99.7	80.5	34.9	40.4
2. Sulfur	365	306	83.8	37.2	10.2	119.0	123.0	9.4	48.3
3. No sulfur	319	263	82.9	30.1	9.4	72.8	79.5	2.3	29.5
4. Sulfur	359	314	87.3	25.6	7.1	113.0	130.5	—2.2	45.9
5. No sulfur	326	272	83.7	44.9	12.8	79.7	88.5	17.0	32.3
6. Sulfur	339	291	85.9	35.6	10.5	93.3	107.5	7.8	37.8
7. Checks	246	183	74.4	27.8	13.1				

[1]75 pounds N and 150 pounds P_2O_5 applied per acre in each treatment, excepting checks. In addition 125 pounds K_2O applied per acre to Nos. 1 and 2, and 62 pounds per acre to Nos. 3 and 4.

As previously indicated Tables II and III summarize average yields from N-P fertilization over a period of years. These results as a whole, are in harmony with those of individual experiments given above. It is notable that average yields of Group 4 (507 pounds plant-

food) were less than that of Group 3 (377 pounds). The average yield of the checks was also less than those of Groups 1, 2, and 3. The reason for this fact is not clear since growing conditions were apparently uniform throughout all unfertilized plots. Although the total increase in yield, 165 sacks, is less than that of Group 3, the per cent increase is greater. The data, as a whole, however, show a consistent upward trend in yields associated with increased use of fertilizer. It is also notable that increase in yields per 100 pounds plant-food applied is practically the same for Groups 2 and 3, being 46.0 and 45.3 sacks respectively.

Table II indicates that costs of N–P fertilizer varied from $11.34 to $52.48 per acre and from $0.167 to $0.318 per sack increase. Obviously, the most practical amount to apply would depend upon the sale value of the crop. Data on this factor are also shown.

The value of sulfur combined with N–P and N–P–K fertilizers was studied. Parallel series of experiments were conducted on three series of green manure plots, namely, old alfalfa sod, 2-year alsike clover, and biennial white sweet clover. All plots were plowed in late spring preparatory to planting. N and P were combined in a 1 to 2 ratio on all fertilized plots. Potash was added to the fertilizer used on certain plots in the proportions of 1.6 and .8 in both sulfur and non-sulfur series. Sulfur-containing fertilizers were compounded from the following materials, namely, ammonium sulphate, superphosphate, and sulphate of potash; and non-sulfur-containing fertilizers from urea, treble phosphate, and muriate of potash. The weight of combined sulfur applied in the 1–2–1.6, 1–2–.8 and 1–2–0 mixtures was calculated at 198, 175, and 152 pounds per acre, respectively.

Average yields and grades of potatoes from each of the three fertilizer tests under the different green manure conditions indicated, closely parallel each other. General averages are summarized in Table III. Under conditions obtaining in these tests N–P–K plots in the sulfur series slightly outyielded those fertilized with N–P only. In the non-sulfur series, plots treated with N–P–K fertilizers with a high proportion of potash produced a greater per cent increase yield than those low in potash. The average increase in total yields over checks in the high and low potash sulfur series was 48.3 and 45.9 per cent, respectively, and from the N–P sulfur plots, 37.8 per cent. The average increase in total yield over checks in the high and low potash non-sulfur series was 40.4 and 29.5 per cent respectively, and for the N–P plots, 32.3 per cent. The value of combined sulfur in potato fertilizers of the character indicated and under the soil conditions of Parkdale loam seems definite.

Relation of Soil Reaction to Tuberization, Rate of Growth, Development, and Partial Composition of the Potato

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RESULTS of studies concerning the inter-relation between soil reaction and growth of plants indicate that the intake of plant nutrients is greatly affected by the reaction of the solution in which the plants are grown. The reaction of the soil, therefore, may be expected to exert an influence on the rate of growth, tuberization, and development of the potato plant and tuber. Soil reaction may also affect the quality of potatoes by influencing the starch and moisture content of the tuber.

Smooth Rural potato plants were grown in 30 plots 50 x 12 feet in size, four rows per plot with guard rows between. Seed pieces weighed 1 to 1½ ounces each. An equal number of seed pieces and same weight of seed per plot were planted on May 25, 1932. The hydrogen-ion concentration of the soil was increased by the addition of sulphuric acid (C. P. 1.84 sp. gr.) which was diluted and applied with a sprinkling can after plowing. The hydrogen-ion concentration was decreased by the addition of hydrated lime. The soil reaction of each plot was determined by the quinhydrone electrometric method on June 4, July 29, August 26 and September 21. Utilizing the determinations of July 29, the 30 plots were grouped into six ranges of pH with five plots in each range of reaction.

Twenty hills were harvested from each of the plots at each of five periods during the growing season, and data obtained upon fresh weight of tops, number of stalks, fresh weight of tubers, and number of tubers. All tubers regardless of size were included. The tubers from the 100 hills of each reaction range were then placed together and divided into 25-gram classes. The percentage of dry matter and starch of five sizes of tubers at each harvest was determined also. Starch was determined by digestion with taka-diastase and acid hydrolysis, the reducing sugars being determined by the picric acid reduction method.

The results of the growth data are shown in Table I. The increases in fresh weight of tops and fresh weight of tubers of the treatments as a whole are very similar to the data presented in a previous paper (3). However, there are some distinctive differences in growth of the plants at the various soil reactions. The fresh weight of the tops at the lowest pH range, 4.68 to 4.90, is smaller in most cases than those grown at higher pH values, whereas those grown at the highest pH had the largest fresh weight of tops at each harvest period. The decrease in fresh weight of tops of all treatments on September 20 is due to the drying of the lower leaves. The early decrease in fresh weight of tops grown at pH 5.64–6.05 indicates the earlier maturity of the vines of these

plots. The fresh weight of tubers per plant at pH 4.68–4.90 is also the smallest in four of the five harvests.

TABLE I—GROWTH OF THE POTATO PLANT AT VARIOUS SOIL REACTIONS

Soil Reaction (pH)	Average per Plant			Average Fresh Wt. per Tuber (Gms.)	Increase per Hill (Gms.)
	Fresh Wt. Tops (Gms.)	No. Tubers	Wt. Tubers (Gms.)		
	Harvested 68 Days After Planting, Aug. 1				
4.68–4.90	195.21	4.96	78.42	16.05	——
4.98–5.55	277.33	5.87	116.39	19.82	——
5.64–6.05	338.77	5.37	138.54	25.80	——
6.08–6.51	336.15	4.80	114.52	23.86	——
6.58–6.84	350.11	5.24	109.51	20.90	——
7.16–7.45	371.45	5.21	126.91	24.36	——
	Harvested 83 Days After Planting, Aug. 16				
4.68–4.90	336.50	6.52	279.31	42.84	200.89
4.98–5.55	415.88	7.34	342.65	46.68	226.26
5.64–6.05	361.73	7.57	357.95	47.29	219.41
6.08–6.51	431.19	7.25	306.54	42.28	192.02
6.58–6.84	443.23	6.60	313.97	47.57	204.46
7.16–7.45	443.95	6.52	316.74	48.58	189.83
	Harvested 97 Days After Planting, Aug. 30				
4.68–4.90	418.29	7.10	536.87	75.62	257.56
4.98–5.55	407.94	7.56	553.97	73.28	211.32
5.64–6.05	358.33	7.27	497.96	68.50	140.01
6.08–6.51	421.13	7.30	548.00	75.07	241.46
6.58–6.84	411.77	6.89	510.22	74.05	196.25
7.16–7.45	552.67	6.32	496.65	78.58	179.91
	Harvested 118 Days After Planting, Sept. 20				
4.68–4.90	157.62	5.61	534.35	95.25	0
4.98–5.55	210.35	6.78	693.50	102.29	139.53
5.64–6.05	148.27	5.93	560.81	94.57	62.85
6.08–6.51	200.43	5.34	649.43	121.62	101.43
6.58–6.84	204.11	5.80	641.66	110.63	131.44
7.16–7.45	228.77	5.91	585.23	99.02	88.58
	Harvested 139 Days After Planting, Oct. 11				
4.68–4.90	*	3.65	570.15	156.21	35.80
4.98–5.55	*	5.42	713.03	131.56	19.53
5.64–6.05	*	5.53	730.41	132.08	169.60
6.08–6.51	*	5.15	700.54	136.03	51.11
6.58–6.84	*	5.02	725.86	144.59	84.20
7.16–7.45	*	4.59	784.21	170.85	198.98

*Tops dry and dead.

With the exception of those at the highest acidity the differences in fresh weight of tubers of the various reactions at the first two or three harvests are not very great. At the fourth and fifth harvests, however, the differences become more marked. At maturity the highest acidity plots produced the lowest weight of tubers per plant and the plots of lowest acidity yielded the greatest weight with the intermediate reactions producing yields within these extremes. In view of the results obtained at other stations it is interesting to note that in the first four harvests the greatest yields

TABLE II—Development of Dry Matter and Starch During the Growing Season in Tubers of Different Sizes and Grown at Various Soil Reactions

Size of Tubers (gms.)	Soil Reaction (pH)														
	4.68–4.90					5.64–6.05					7.16–7.45				
	0–1	1–50	50–100	100–150	200–250	0–1	1–50	50–100	100–150	200–250	0–1	1–50	50–100	100–150	200–250
	Dry Matter (Per cent)														
Date of harvest															
Aug. 1	15.4	16.3	15.9	16.8	†	15.5	17.4	16.8	17.2	†	16.0	16.9	16.9	16.6	†
Aug. 16	14.0	17.3	19.8	18.3	17.9	14.2	17.0	20.1	20.6	19.6	14.4	19.4	20.2	18.3	17.9
Aug. 30	9.7	19.2	22.8	22.7	19.9	10.5	18.4	23.3	21.9	23.1	12.5	18.7	20.6	20.9	22.5
Sept. 20	6.7	21.3	22.0	23.9	23.0	9.7	20.8	22.7	21.9	24.9	6.0	20.6	23.3	22.5	21.4
Oct. 11	*	20.4	23.2	24.9	23.0	*	20.2	22.1	25.2	23.0	*	21.4	21.8	23.6	22.5
	Starch Percentage (Dry Basis)														
Aug. 1	47.8	53.1	56.0	56.7	†	46.4	54.0	53.4	54.7	†	45.5	49.7	52.7	53.3	†
Aug. 16	43.1	53.1	60.7	56.2	58.4	42.3	58.9	61.6	63.6	60.7	40.3	55.6	60.0	55.6	56.2
Aug. 30	34.2	56.4	62.6	63.4	61.8	33.4	56.4	64.3	62.6	63.3	38.0	54.9	59.5	57.7	60.7
Sept. 20	13.1	59.1	61.6	61.6	62.0	29.6	58.4	63.4	62.9	66.5	13.1	55.8	60.0	59.3	61.0
Oct. 11	*	54.5	64.6	64.6	62.0	*	66.7	65.9	68.4	69 5	*	60.0	59.8	59.3	63.3
	Starch Percentage (Fresh Basis)														
Aug. 1	7.36	8.65	8.90	9.53	†	7.19	9.40	8.97	9.41	†	7.28	8.40	8.91	8.85	†
Aug. 16	6.03	9.19	12.02	10.28	10.45	6.01	10.01	12.38	13.10	11.90	5.80	10.78	12.12	10.17	10.06
Aug. 30	3.32	10.83	14.27	14.39	12.30	3.51	10.38	14.98	13.71	14.62	4.75	10.26	12.26	12.06	13.66
Sept. 20	0.88	12.59	13.55	14.72	14.26	2.87	12.15	14.39	13.77	16.56	0.79	11.49	13.98	13.34	13.05
Oct. 11	*	11.12	14.99	16.08	14.26	*	13.47	14.56	17.24	15.98	*	12.84	13.04	13.99	14.24

*Tubers of this size have been resorbed and have disappeared

†No tubers of this size present.

were obtained on the plots at pH 4.98–5.55 or pH 5.64–6.05. By applying sufficient lime to change the soil reaction from pH 4.8–5.0 to pH 6.8–7.5, Bushnell (1) found the yields of potatoes grown at the latter reaction to be much reduced. Wessels (5) found the greatest total yields of Irish Cobbler and Green Mountain tubers at a soil reaction of pH 5.2–5.6. The rapid increase in weight at pH 7.16–7.45 between the fourth and fifth harvest appears to be due to the late maturity of the plants in these plots. A similar increase at pH 5.64–6.05 cannot be accounted for.

Clark (2) states that practically the entire crop of tubers was set at the beginning of the period of tuber development, probably within the space of a very few days. These experiments as well as those previously reported (3) do not bear this out. At most of the soil reactions tuber setting has occurred as late as the period between August 16 and August 30. The subsequent decrease in number of tubers per plant is due to the resorption of the smaller tubers as the plant approaches maturity.

At each of the soil reactions the dry matter percentages of tubers weighing less than 1 gram rapidly decrease after the first harvest whereas tubers weighing more than 1 gram continue to increase in dry matter percentage until the third, fourth, or fifth harvest. At the fifth harvest none of the smallest size tubers were found, for the contents had been resorbed; in some cases the periderm remained.

No consistent differences are noticeable in dry weight percentage between the various sizes at the first harvest. At all of the subsequent digging dates, however, differences in percentage of dry matter are noticeable even when the smallest size is not considered. In the majority of cases, the tubers of the 50 to 100 gram and 100 to 150 gram sizes have the largest dry matter percentages. The largest size (200–250 grams) tubers grown at pH 4.68–4.90 are lower in dry matter percentage than the 100 to 150 gram tubers. Considering the tubers of 50 grams and over, the dry matter percentage in the tubers grown at pH 5.64–6.05 is higher, in seven out of 14 cases, and in three cases equal to or within 0.1 per cent of those at the higher or lower soil reactions.

Since differences in dry matter percentage between tubers grown in soils of various reactions are shown, and since starch constitutes the greater portion of the dry matter of potato tubers, we might expect differences in the starch content of tubers grown at these same reactions. Any differences in starch and dry matter content of potato tubers may also affect their cooking quality. Wessels (4) states that the cooking quality of potatoes grown at a reaction of pH 4.4 was decidedly inferior to that of potatoes grown at a reaction of pH 4.9–5.3.

Similar to the decrease in dry matter percentage is that of the decrease in starch percentage of the tubers weighing less than 1 gram as the plants approach maturity. At all of the soil reactions studied, either the starch and other portions of the dry matter do

not enter the newly forming tubers as readily later in the season as earlier or they are transported from the small tubers already formed to the larger tubers or other portions of the plant. The increase in dry matter of tubers of the larger sizes, however, is more marked than that of the starch percentage calculated on the dry basis. It is evident also that tubers up to 50 grams in weight, in most cases, are lower in percentage of starch than those above 50 grams although no actual decrease in percentage on the fresh basis is shown in the 1- to 50-gram size until the last harvest of tubers grown in soil of pH 4.68–4.90.

In tubers more than 1 gram in weight, with one exception, the starch percentage on the dry basis is lowest at the first harvest.

Tubers of marketable size (above 50 grams) usually contain the highest percentage of starch at the last harvest although this is not so marked in the 50- to 100-gram tubers when grown in soil with a reaction of pH 7.16–7.45.

The starch percentage, on the fresh basis, of the marketable tubers at the last harvest when grown in soil of pH 7.16–7.45 was lower than that of tubers grown in the more acid soils. With only a few exceptions this also is true of tubers at all five harvests. In general, the starch percentage of tubers grown at a soil reaction of pH 5.64–6.05 is higher than that of tubers grown at either the higher or lower pH range.

Mealiness of potatoes, when cooked, is due partly to the content of starch and moisture or the ratio between the two. Excessive mealiness often is undesirable in potatoes cooked by boiling because of the sloughing off of the outer layers resulting in the potato falling apart. Preliminary boiling tests indicate that immature tubers and tubers grown at a reaction of pH 7.16–7.45 are less objectionable in this regard than mature tubers or those grown at a reaction of pH 5.64–6.05. In these experiments a relationship is indicated between better table quality of potatoes for boiling and a somewhat lower percentage of starch as brought about by immature harvesting or growth at soil reactions of rather high pH.

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Effects of Temperature and Humidity Upon Length of Rest Period of Tubers of Jerusalem Artichoke (*Helianthus tuberosus*)

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THE experimental work reported in this paper is a portion of a more extensive study concerning the nature and extent of the rest period in the Jerusalem Artichoke, and was intended, primarily, to determine the conditions of temperature and moisture which will most effectively break the normal rest period of these tubers. It is conceivable that under certain conditions of obtaining, transporting, and planting seed stock in warm regions a requisite low temperature might not occur at any time.

Boswell (1) has already called attention to the surprisingly long rest period of the Jerusalem Artichoke and to differences in the length of rest period shown by various varieties when the tubers are not subjected to the low temperatures such as normally occur in the central to northern regions of the United States.

Materials and Methods

Tubers of four of the commercially promising varieties of Jerusalem Artichoke from Dr. D. N. Shoemaker's collection at Arlington Experiment Farm, Va., namely, White Improved, Chicago, Waterer, and Tait were dug during the last week in November, 1931, after the tops of the plants had been completely killed by frosts and before any freezing of the soil had occurred. Thirty-five samples of 25 to 30 approximately 1-ounce tubers each were selected from each variety. Of these samples, 14 were put in ordinary manila paper bags, seven being placed at 36 degrees F (average relative humidity 87.5), and the other seven at 50 degrees F (average relative humidity 80.7) in constant temperature chambers of the Cold Storage Laboratory.

The tubers of each of the other 21 samples were carefully packed in damp clay in manila paper bags, and the latter placed inside snug-fitting cloth bags. Seven of these clay-packed samples were then placed in each of three constant temperature chambers held at 18 degrees F (very low humidity), 32 degrees F (average relative humidity 86.5), and 32 degrees F (average relative humidity 57.6), respectively. An additional sample of about 250 tubers of each variety was also placed in a well drained pit covered with about 8 inches of soil in an open field, care being taken to keep layers of tubers separated by thin layers of soil. No records were taken as to temperatures existing in the field pits. The mean and minimum air temperatures during the various individual 15-day periods from

time of placing of the tubers in the pits until removal of the last samples are given in Table I.

TABLE I—AVERAGE AND MINIMUM AIR TEMPERATURES OCCURRING DURING SUCCESSIVE 15-DAY PERIODS WHILE TUBERS WERE STORED IN FIELD PITS (DEGREES F)

Period (Days After Placing in Pit)	White Improved		Chicago and Waterer		Tait	
	Average	Minimum	Average	Minimum	Average	Minimum
1–15	48.5	26	46.7	25	45.2	25
16–30	46.7	25	43.7	24	44.4	24
31–45	43.7	24	48.3	30	45.7	31
46–60	48.3	30	44.3	22	47.9	29
61–75	44.3	22	44.6	28	41.9	22
76–90	44.6	28	42.4	21	42.8	21
91–105	42.4	21	—	—	—	—

While the average air temperature was in every case above 40 degrees F, it is worthy of note that the minimum temperature was below 32 degrees F for one or more days in each of the 15-day periods.

At successive intervals of 15 days after the beginning of the treatments (November 25 for White Improved, December 4 for Tait, and December 12 for Chicago and Waterer) samples of each variety were removed from storage and the field pits, and planted in flats of moist peat in a greenhouse. The peat was kept moist thereafter, and the greenhouse temperatures held at 50 to 55 degrees F at night, and 60 to 70 during the day throughout the winter and spring. Near the end of the experimental period it was impossible to keep the temperatures from going considerably higher on warm days.

Every 15 days after planting, the tubers of each sample were carefully removed from the peat, records taken as to the extent of sprout growth, rooting, and the amount of rotting of tubers, and the tubers carefully replanted, such examinations being continued until all sound tubers had sprouted.

RESULTS

For the same reasons as those set forth by Boswell (1), the number of days from planting required for 50 per cent of the sound tubers in any sample to sprout, was used as the index of length of rest period, rather than the period from planting to first sprouting or to 100 per cent sprouting. The relative degree of shortening of the rest period by storage under the various conditions for the designated periods can be seen by comparison of the data with that for the control samples which were planted in peat in the greenhouse shortly after digging in November.

At 18 degrees F the natural rest period of the tubers is somewhat shortened but only relatively slowly. (See A in Table II). In no case did tubers subjected to this temperature show 50 per

cent sprouting in less than 45 days after planting, and then only after a storage period of 90 days. By comparing the sprouting time (time from storage of tubers to date of 50 per cent sprouting) of the frozen tubers with that of tubers planted immediately after harvest, it will be seen that there is but very slight advantage, and in several cases an actual disadvantage in holding the tubers at 18 degrees F. This is brought out more clearly by the data of Table II(B) representing the differences in number of days between the sum of the days in storage plus days to 50 per cent sprouting of tubers for stored samples, and the number of days between planting and 50 per cent sprouting for the corresponding varietal samples planted immediately after harvest. Actual freezing injury occurred under conditions of the present experiment, to tubers stored at 18 degrees F (vide infra), therefore, the relatively slow shortening of the rest period at this temperature may have been at least partially a result of the injury rather than a direct result of the temperature alone.

Storage at 32 degrees F with high humidity, at 32 degrees with low humidity, and at 36 degrees with high humidity were all about equally effective in shortening the rest period, although the sprout growth appeared more vigorous, once initiated, among those lots exposed to either high or low humidity at 32 degrees than among those held at 36 degrees. Fifty per cent sprouting was obtained within 15 days of the planting date after chilling for 45 to 60 days, varying somewhat with the variety. Although not evident from the data of Table II(A), observations showed that with increasing length of storage beyond 60 days the sprouting time was progressively shortened, 50 per cent sprouting occurring in less than 7 days after planting following 90 days of chilling. The maximum gain in sprouting time as compared with the control plantings was attained by storage for 15 to 45 days, depending upon the variety.

The effect of the 50-degree temperature upon reduction of time to 50 per cent sprouting accumulated slowly. Ninety days at this temperature were required to induce 50 per cent sprouting within 15 days after planting. At this temperature the greatest gain in sprouting time, as compared with the control plantings occurred after 45 to 75 days storage. The latter range is fully 30 days longer than the corresponding time required to attain the same end with 32 or 36 degrees F storage.

With the fluctuating temperatures obtaining in the field pit, shortening of the rest period was intermediate between that obtained at 32 or 36 and at 50 degrees F. From 30 to 60 days, according to the variety, were required in this case to give the maximum gain in sprouting time.

Considerable differences were also found in the amount of rot which developed at the different temperatures and during subsequent sprouting in the greenhouse (Table II (C)). A high percentage of rotting occurred in all varieties as a result of exposing to temperatures of 18 and 50 degrees F.

TABLE II—EFFECT OF STORING TUBERS OF JERUSALEM ARTICHOKE UNDER VARIOUS CONDITIONS AND FOR DIFFERENT LENGTHS OF TIME, ON SUBSEQUENT SPROUTING, AND ON SUSCEPTIBILITY TO ROTS

Period of Exposure (Days)	(A) Days to 50 Per cent Sprouting After Exposure to Low Temperature				(B) Days Gained in Earliness of Sprouting*				(C) Per cent of Tubers Rotted Prior to June 1, 1932‡			
	White Improved	Chicago	Waterer	Tait	White Improved	Chicago	Waterer	Tait	White Improved	Chicago	Waterer	Tait
1. 18 Degrees F Very Low Humidity												
15	165	120	135	120	—30	15	40	15	88	5	15	54
30	120	120	135	120	0	0	30	0	84	10	17	52
45	120	105	—†	120	—15	0	—	—15	73	33	63	42
60	105	90	105	105	—15	0	30	—15	87	19	33	50
75	90	60	—†	60	—15	15	—	15	77	35	67	76
90	75	60	—†	45	—15	0	—	15	91	20	100	77
105	60	—	—	—	—15	—	—	—	92	—	—	—
2. 32 Degrees F Low Humidity (58 Per cent)												
15	75	45	90	60	60	90	90	75	0	0	0	0
30	30	30	45	30	90	90	120	90	0	0	0	12
45	30	15	15	15	75	90	135	90	23	0	0	0
60	15	15	15	15	75	75	120	75	0	5	0	0
75	15	15	15	15	60	60	105	60	0	0	9	0
90	15	15	15	15	45	45	90	45	5	0	0	27
105	15	—	—	—	30	—	—	—	0	—	—	—
3. 32 Degrees F High Humidity (87 Per cent)												
15	60	45	105	60	75	90	75	75	0	0	12	0
30	30	30	45	45	90	90	120	75	0	0	0	0
45	30	15	15	30	75	90	135	75	0	0	0	0
60	15	15	15	15	75	75	120	75	0	0	0	0
75	15	15	15	15	60	60	105	60	0	0	0	0
90	15	15	15	15	45	45	90	45	0	0	0	0
105	15	—	—	—	30	—	—	—	0	0	0	0

4. 36 Degrees F High Humidity (88 Per cent)												
15	60	75	120	60	75	60	60	75	9	0	19	0
30	30	30	30	45	90	90	135	75	0	0	0	0
45	15	15	15	30	90	90	135	75	0	0	0	0
60	15	15	15	15	75	75	120	75	0	0	0	0
75	15	15	15	15	60	60	105	60	0	0	0	0
90	15	15	15	15	45	45	90	45	0	0	0	0
105	15	—	—	—	30	—	—	—	0	—	—	—
5. 50 Degrees F High Humidity (81 Per cent)												
15	135	135	135	105	0	0	45	30	4	19	29	8
30	90	135	150	75	30	—15	15	45	4	63	48	0
45	105	90	90	45	0	15	60	60	5	0	50	0
60	75	45	60	30	15	45	75	60	32	15	36	4
75	30	45	30	15	45	30	90	60	4	5	19	0
90	15	30	30	15	45	30	75	45	72	7	0	5
105	15	—	—	—	30	—	—	—	72	—	—	—
6. Field Pit—Fluctuating Temperature												
15	105	90	135	75	30	45	45	60	0	0	0	4
30	75	45	105	30	45	75	60	90	0	0	29	0
45	45	30	45	30	60	75	105	75	0	0	0	0
60	15	15	15	15	75	75	120	75	0	0	0	0
75	15	15	15	15	60	60	105	60	0	0	0	0
90	15	15	15	15	45	45	90	45	0	0	0	0
105	15	—	—	—	30	—	—	—	0	—	—	—
Control Samples Planted Immediately After Digging in November												
	150	150	195	150								

*Number days in storage plus days to 50 per cent sprouting subtracted from number days to 50 per cent sprouting of control plantings.
†All tubers rotted without sprouting.
‡Percentage based on number of sound tubers at time of preceding examination.

In general the losses from rotting at 18 degrees F were very high, but it must be pointed out that these losses were not due primarily to growth of microorganisms. Upon removal of the tubers from the storage chamber at 18 degrees F to the one at 50 degrees for 24 hours, followed by planting in peat in a cool greenhouse, a rapid physical breakdown of the pith tissues occurred. Following this initial breakdown the tubers were readily invaded by rot organisms. In many cases the tissues external to the pith remained apparently sound but sprouts subsequently formed were weak and comparatively slow in developing. At 50 degrees F no evident physical breakdown preceded the rotting by organisms.

Very little rotting occurred when tubers were stored at 32 degrees F high humidity or low humidity, 36 degrees F, or in the field pits with layers of soil separating the layers of tubers.

The present study was not intended as a storage investigation, but the evidence which has accumulated incident to the main purpose is in excellent agreement with unpublished data obtained by Messrs. R. C. Wright and T. M. Whiteman of the United States Department of Agriculture relative to cold storage of the Jerusalem Artichoke, and with the findings of Traub, Thor, Willaman, and Oliver (2).

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Effect of Storage Temperature on Histological and Microchemical Changes and on Propagation Value of Potato Tubers

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BECAUSE of its practical importance in New York and because of the number of discrepancies and unexplained phenomena in a large volume of research on the subject, a study of the effects of storage conditions on propagation value of potatoes was begun in 1930. E. V. Hardenburg and A. L. Wilson were responsible for initiating that project, on which the author did rather extensive preliminary work. The present paper gives the results of studies which were planned on the basis of the findings of that earlier work. The purposes were to secure more accurate field results which would justify being carefully studied, to follow up an indication from the preceding research that one of the most important determinants of propagation value of potatoes was the degree of development of the buds or sprouts, and to add to the data already available such information as might help to complete the understanding of the problem.

On December 17, 1931, 48 samples of potatoes, all of equal weight, were placed at storage temperatures of 50, 40, 35, and 32 degrees F, all with about 90 per cent humidity. These samples consisted either of 100 uninjured tubers weighing approximately 2 ounces each and varying less than a half ounce from this weight or of 75 tubers averaging 2.71 ounces. Lots containing 75 tubers were, in general, not compared with lots containing 100 tubers. Green Mountain potatoes of a supposed clonal strain were used.

The samples were stored in shelves in rigid baskets, admittedly not according to commercial practice, but in such a way that their temperatures and humidities were very closely those recorded by the hygrothermographs and also so that circulation of air was about the same for all samples. All samples were weighed several times during the period of storage. On December 17, January 22, March 24, June 1, June 16, and June 29 apical eyes, and, separately, lateral and basal eyes were preserved and prepared by the paraffin method for anatomical, histological, and cell wall microchemical study. Samples for microchemical study alone were prepared by a method which subjected the material to no active chemicals.

The results show very slight and insignificant differences in shrinkage between the 40-, the 35- and the 32-degree storages until May 24, the total shrinkage of these samples up to that time being 3.3 per cent of the original weight. By June 29, the values were 4.21 per cent at 40 degrees, 4.00 per cent at 35 degrees, and 4.51 per cent at 32 degrees. The odds for significance of the greater shrinkage at 32 degrees than at 35 are greater than 1000:1 in spite of the fact that at this date only 3 samples of each remained in

storage. The samples in the 50-degree storage lost hardly any more moisture than the others until after March 13, when apical sprouts had become 5 mm long. By May 24 they had lost 8.71 per cent, and by June 29 when long sprouts had been removed the loss was 21.94 per cent.

Since it had appeared that one of the main differences in yield from potatoes stored under different conditions arose from the variation in their sprout growth and the time they came up, plantings were made at different dates, namely, May 25 with no sprouts removed, June 16 with sprouts of the 50-degree storage samples removed, and July 7 with no further sprouts removed.

TABLE I—EFFECT OF STORAGE TEMPERATURE OF SEED POTATOES UPON SUBSEQUENT GROWTH AND PRODUCTIVITY

Seed Storage Temperature (Degrees F)	Days after Planting when 75 per cent (Approx.) of Plants Had Appeared	Number of Stalks per Plant	Number of Tubers per Plant	Total Weight of Tubers (Yield in Bushels per Acre) Corrected for Soil Variation
		Planted May 25		
50	14.0	2.0	7.5	458.1±6.67
40	24.2	2.4	8.9	412.5±6.51
35	27.6	2.8	8.7	389.2±5.25
32	29.6	3.4	9.4	351.0±3.45
		Planted June 16		
50	16.0	4.1	10.6	348.2± 5.98
40	17.1	3.0	8.5	383.4± 2.23
35	21.0	2.9	7.9	363.2±10.73
		Planted July 7		
50	12.6	4.8	12.5	228.7± 1.28
40	16.0	4.4	12.7	245.1± 3.98
35	21.0	4.2	9.7	206.0± 5.25
32	25.3	5.3	10.3	176.6± 1.06

Livermore (2) has summarized the research showing what accuracy has been obtained in potato experiments of the type where the soil was not treated differently in different plots. He called attention to the fact that potato replicates have always been found more variable than replicates in tests of grains. The lowest values obtained by certain workers for the probable error of the single replicate have been: Myers and Perry (New York, 1921) 14.7 per cent, Krantz (Minnesota, 1923) 12.2 per cent, Livermore (New York, 1926) 7.1 per cent. In this experiment several means were used to reduce error. (1) Whole tubers were used, so that the largest bud of each tuber would always be planted and so that danger of rotting would be lessened. (2) The 40-degree samples, which were equal in number to all the other samples together, were used as check rows, not checks scattered here and there throughout the plot, but check rows on both sides of each test row and with roots in the same soil as the test rows. (3) Plots were long, 90 feet by three feet, so that all plots ran over different spots of soil. Tubers were exactly equally spaced and covered. As a result the

probable error of the individual replicate was 2.63 per cent for the 32-degree, the 35-degree and the 50-degree treatments which were checked, as explained, by the 40-degree treatment rows. According to the equation used by Livermore for showing the relation between variability, number of replicates needed, and differences to be shown significant, three plantings of each treatment with this percentage error would be as good as 43 which had a percentage error of 10.

The time required for potato plants to appear above the surface of the ground depended markedly on previous storage temperature. Likewise, total weight of tubers, total number of tubers, and total number of stalks produced per plant varied markedly with the different treatments. A brief summary of these relationships is made in Table I.

In the May 25 planting, plants of the 50-degree treatment, which had come up considerably ahead of others, died about a week sooner than other plants. In the July 7 planting the 50-degree plants passed through the various stages of senescence about 3 days ahead of the other plants.

From each of the samples of apical eyes taken at stated times four eyes were, in general, sectioned and mounted serially. From samples taken March 24, however, only single eyes were sampled. Slides for use in microchemical studies, each bearing four sections representing the longest buds of the four eyes, were prepared at the same time. They were mounted without a fixative. Eyes were cut with the blade of the microtome parallel to the periderm and moving through the periderm from its outer layer. The results of measurements of sprout lengths during the storage period are presented in Table II.

TABLE II—Effect of Temperature upon Length of Potato Sprouts in Storage

Date of Sampling	Storage Temperature (Degrees F) 50 (mm.)	40 (mm.)	35 (mm.)	32 (mm.)
Dec. 17......	.2± .01	.2±.01	.2±.01	.2±.01
Jan. 22......	.3± .03	.2±.01	.2±.01	.2±.01
Mar. 24.....	5.3	.2	.2	.3
June 1.......	119.4±17.96	.6±.10	.4±.04	.2±.02
June 16......	.9*	1.1±.15		
June 29......	2.8± .46†	1.5±.13	.2±.01	.2±'01

*Only two eyes of this sample were sectioned, and one of these had no uninjured buds. Naturally the measurement of only the one sound bud is given, since other buds in other eyes would be the ones to grow. The 50 degree samples were desprouted June 5 and all perceptible buds were scraped out of the eyes. The buds found in the 50 degree sample after June 5 are consequently of a second crop.

†Two of the four eyes sectioned had no uninjured buds.

The inconsistency of the progressive differences between the 35-degree and the 32-degree-eyes indicates very clearly the need for sectioning more apical eyes from these treatments. Lateral and basal eyes, not yet sectioned, may aid in establishing the true relative rates of growth.

In structure practically no development took place in the 35- and the 32-degree storages. Under these conditions lignified xylem never appeared in the sprout itself. The meristematic tissues, especially the apical, had thick walls of which the middle lamella alone stained. The youngest leaf primordia always were exceedingly simple in form and fitted closely around the stem apex. The regions just below the apical meristems had many globular bodies, often larger than the nuclei, which were neither fat nor oil globules. According to their position, structure, and color these were undoubtedly the tannin vessicles found by Artschwager (1).

In none of the storage buds or sprouts in any treatment did differentiation of tissues so sharp or extreme take place as was found in apices of plants grown in light. Divergences from the original histological structure did not develop in the 40- and the 50-degree storages until the length of the sprouts increased. In the buds of the 40-degree storage at the latest date of sampling no lignified xylem had yet developed. In the sprouts growing at 50 degrees by March 24, lignified xylem vessels were extending through the lower parts of the sprout, but never near the tip. The tips of the largest sprouts studied (50 degrees, June 1) were markedly different from the tips of the undeveloped buds. In this case cells just back from the meristem, instead of being irregular in shape and apparently irregularly placed, were definitely rectangular in cross section and so aligned as to make their origins from certain common initials very evident. These tips were also distinguished by the fact that they were producing hairs and had leaves more complex than those which are characteristic of small buds.

No further suberization of the periderm took place in any storage for the duration of the experiment. Starch grains were never found in the young buds, but in the long sprouts tissues even quite close to the apical meristems contained many spherical grains. These grains had about 1/10 or 1/20 the volume of the average grain of the old tuber. There was never a trace of suberin over the bud tip itself or on any part of the bud until the sprout had grown quite large. The surfaces of long sprouts were lightly suberized at their bases. Cellulose walls of the older tissues showed their greater age by more intense reactions to tests for cellulose. Even in sprouts which did not show much histological differentiation, there was often definite localization of proteinaceous material.

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Depth of Planting Experiments for the Control of Rhizoctonia on Potatoes

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THE Black Scurf (*Corticum vagum* B & C), of the potato popularly known as rhizoctonia, takes considerable toll each year from the potato crop in the northern potato producing regions of the United States. The use of chemicals in killing or inhibiting the growth of rhizoctonia from the sclerotia on the tubers has proved their value in successful potato production, yet there has been a great hesitancy on the part of potato growers generally to adopt seed treating practices. This fact prompted the writer to investigate the cultural phases of rhizoctonia control.

The cultural phases of rhizoctonia control have been referred to directly and indirectly by many of the workers on this disease. The two chief environmental factors studied with reference to the virulence and severity of rhizoctonia on potato stems were soil temperatures and soil moisture. The work of Richards in Wisconsin demonstrated also the relationship of rapidity of growth of the young sprout to the severity of the infection. While there are differences of opinion concerning the rôles of soil moisture in the rapidity and severity of rhizoctonia and soil temperatures, yet it is quite evident that these two factors must be considered together.

The work at the Northwest Station on the depth of planting tests with seed potatoes was started in 1930 in connection with and in comparison with the regular seed treatment tests which have been under way for a number of years. An attempt was made in these depth of planting tests to compare deep, medium, and shallow planting of rhizoctonia-infected seed pieces with deep planted, shallow covered, and shallow planted, shallow covered seed stock. Mosaic-free Triumphs quite uniformly dotted with rhizoctonia sclerotia were cut into uniformly sized seed pieces for all plots, both treated and untreated seed was planted at the several depths and the 25-hill plots were replicated four times. One replication was dug in mid-summer for the summer inspection of stems and the remaining plots were left for the fall harvesting records. The seed was planted in trenches which were accurately made and the following depths of planting and cover were used, namely, 6 inches deep with 6 inches cover, 4 inches deep with 4 inches cover, 4 inches deep with 2 inches cover, 2 inches deep with 2 inches cover, and 2 inches deep with 1 inch cover.

Time will not permit the giving of tabulated data. Only summaries and general conclusions can be drawn. The data in detail is on file in the Report of the Horticulturist, Northwest Experiment Station, for 1933.

It is evident from the results obtained that stems from seed pieces covered to a depth of 6 inches show more than 90 per cent

infection, also that the per cent of infection and severity of infection decrease as the depth of cover of seed pieces decreases to around 30 per cent where the seed is covered 1 and 2 inches deep. The severity of infection also decreases as the depth of cover becomes less. It was apparent that a higher percentage of clean stems was obtained at all depths when treated seed was used than when infected untreated seed was planted.

The harvesting records for the untreated and treated seed when summarized show that for the untreated seed a majority of tubers (66 per cent) at the shallow depth were freely specked with rhizoctonia sclerotia. The percentage increased, however, to 75 per cent at the 6-inch depth of planting. The yields from the untreated seed with 1 and 2 inches of cover ranged from 200 bushels per acre downward to 150 bushels per acre for the 6-inch depth of planting.

For the treated seed, the tubers were considerably brighter and the severity of the sclerotia infestation was less than in the untreated seed. The percentages of disease infection ranged from 50 on the shallow depths to 66 at the 6-inch depth. The yields from treated seed with 1 and 2 inches of cover was slightly less than for untreated seed, however, treated seed with 4 and 6 inches of cover yielded from 10 to 15 per cent more than the untreated seed at the same depths.

The results from the depth of planting seed thus far in the trials indicate that shallow covering (1 to 2 inches) at planting time has considerable merit, especially when consideration is given to the fact that relatively dry weather has prevailed through the past 2 years of the test. The results also indicate that seed treatment is of particular importance when the seed pieces are planted 4 or more inches deep. For the present it looks reasonable for the grower to continue his seed treatment practices, however, when dormant seed is used a light to moderate coverage of the seed appears preferable to deep planting and deep coverage.

Controlling the Shrinkage of Skinned Potatoes in Storage

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THE storage of potatoes has been studied from many angles but there does not seem to be any published investigational work to show the direct effect of skinning on the loss of weight during storage. The purpose of this investigation was to find means by which the large shrinkage in weight of skinned potatoes and the resultant deterioration could be easily and inexpensively checked and controlled. The principles involved in checking the shrinkage of skinned potatoes are the same for those that are cut and bruised incident to harvesting and handling.

It is a well established fact that large losses are incurred each year in harvesting and handling the potato crop through skinning, bruising, cutting, and resultant deterioration of the tubers. Some of this loss is avoidable by more careful harvesting and handling, but it is almost impossible to harvest potatoes without some injury unless they are very carefully dug after the skin is thoroughly set and the ground is free from stones. Since most of the potatoes grown in the United States are harvested when the skin of the tubers slips rather easily the losses from harvesting and handling are enormous and very widely distributed.

In the Norfolk and Eastern Shore Districts of Virginia (1) in 1928 it was estimated that the loss to the growers caused by cuts and bruises was approximately $80,000 exclusive of loss from the rapid shrinkage that resulted from skinning the tubers. R. C. Hastings (5) reported a conservative estimate of $500,000 loss incurred in handling the 1929 North Dakota crop through avoidable cuts, bruises, and the resultant deterioration of the potatoes. To lose part of the crop means an increase in the average cost per bushel.

Several physiological studies throw light upon the results obtained in this investigation of the shrinkage of skinned potatoes. Appleman and Miller (2) found that immature potatoes showed a greater respiratory activity immediately after harvest than mature tubers. These investigators account for this increased respiratory activity by the greater permeability of the tender skin of the immature tubers to the exchange of gases. Kimbrough (6) showed that the respiration rates are high immediately after harvesting for 8 or 10 days and accompanied by a rather sudden rise in temperature. Lutman (7) found that cutting a potato caused a rapid rise in the respiration rate during the second and third days after the injury with a subsequent gradual fall in the curve to normal.

On the basis of these investigations it is probably safe to conclude that the skinning increased the respiratory activities. As a result of the freshly skinned areas on tubers being more permeable

to the movement of liquids than where the skin has not been removed, the evaporation rates are higher until a new skin periderm is completely developed.

Experimental Procedure

The Irish Cobbler variety of potatoes used in this investigation were from four crops grown on the Arlington Experiment Farm, Roslyn, Va. They were stored there in the experimental storage plant within 3 days after harvest. Consequently, there were no intervening periods during which the storage conditions were unknown.

The potatoes were harvested practically as soon as the vines were completely dead. This gave the assurance of what is commonly termed, "mature potatoes."

To insure uniformity, tubers for this test were carefully hand selected on the basis of medium size, soundness, and freedom from cuts, bruises, and skinned areas. These were distributed by putting a few tubers at a time in each of 12 baskets. This process was repeated until each basket contained an average of approximately 35 pounds of potatoes or about 90 tubers. Then the baskets were grouped into pairs and labeled. All the potatoes in one basket of each pair were skinned in several small areas, amounting to approximately 8 to 10 per cent of the surface. Care was taken not to injure the tissue below the skin. Then the skinned tubers were thoroughly mixed again and put back into the baskets. The object of skinning them by hand was to avoid having the skinned lots possibly more immature than the uninjured tubers. This is liable to occur when the potatoes are skinned by harvesting operations. Each basket was covered with burlap to prevent accidental loss of tubers. The basket of uninjured tubers served as a check.

Goldthwaite (4) found by quantitative analyses and cooking tests that small and large tubers from the same hill are not usually of a like degree of maturity and often the small ones are more mature than the large tubers. The same principle also naturally applies to the medium size tubers.

One basket each of skinned and uninjured potatoes were stored at 32, 36, 40, 50, 60, and 70 degrees F. These temperatures were held practically constant by thermostatic control. By storing the potatoes in baskets, they soon came to the same temperature as that of the rooms in which they were stored. The humidities were adjusted so as to maintain the same saturation deficit of the atmosphere in all the rooms in which the potatoes were stored. Thus, the rate of evaporation was the same in all the rooms. The air circulation in each room was maintained by the use of a 12-inch electric fan. These rooms were entered two or more times daily which provided an exchange of air. The rooms were held in absolute darkness except occasionally when they were electrically lighted for a few minutes at a time. The comparative storage losses were

measured chiefly by periodic weighings. The net weights were recorded weekly. To shorten this paper, the net weights are given bi-weekly for a period of 12 weeks, which is sufficient to show the trend and the progressive percentage of the shrinkage in weight at different periods for the various storage temperatures.

Results

The results given in Table I indicate that the formation of the skin periderm as indicated by prevention of weight loss, requires conditions very similar to those that Artschwager (3) found to be favorable for the development of wound periderm in the potato. He observed that there were no periderm cells at a temperature lower than 44.6 degrees F within the duration of his experiment.

TABLE I—Progressive Percentage Loss in Weight of Four Crops of Skinned and Non-skinned Irish Cobbler Potatoes Held in Rooms with Different Storage Temperatures and the Same Saturation Deficit

Weeks in Storage	Storage Temperature (Degrees F.)											
	32		36		40		50		60		70	
	Skinned	Non-Skinned	S	N-S	S	N-S	S	N-S	S	N-S	S	N-S
2	2.9	.9	1.7	.5	2.9	.4	2.0	.8	1.2	.7	1.7	.8
4	5.7	2.0	2.6	.8	4.4	1.4	2.9	1.2	2.0	1.4	2.4	1.0
6	8.7	2.8	3.6	1.4	5.2	1.9	3.5	1.7	2.4	1.6	2.7	1.5
8	11.2	3.3	4.1	1.7	5.9	2.2	3.7	2.2	2.1[1]	1.5[1]	2.1[1]	1.8[1]
10	13.7	4.4	4.5	1.9	6.7	2.8	4.4	2.6	1.7[1]	1.7[1]	2.6[2]	1.9[2]
12	16.3	5.1	5.0	2.1	7.2	3.2	4.8	2.8	1.8[1]	2.8[1]	2.3[3]	2.3[3]

[1]Average of three crops. [2]Average of two crops. [3]One crop.

At 50 degrees F he observed that the first periderm cells appeared after the fourth day in the Irish Cobbler and in the other varieties after the sixth day. On this basis the progressive percentage losses in weight of skinned potatoes of another variety may be larger than the results given in Table I of those stored at 50 degrees. Artschwager (3) observed periderm cells in those stored at 60 and 70 degrees after the third and second day, respectively, regardless of the variety.

The rates of loss between the skinned and non-skinned Irish Cobbler potatoes were approximately constant during the 12 weeks in storage at 32 degrees, or about three times greater for the skinned than non-skinned potatoes. Even the rate of loss of the non-skinned tubers stored at 32 degrees is higher than similar tubers stored at the other temperatures.

For some reason, neither skinned nor non-skinned potatoes held at 36 degrees lost as much in weight as the corresponding lots at 40 degrees. The progressive losses in weight of the skinned potatoes held at 36 degrees were from approximately two and a half to three times greater than the uninjured tubers.

The shrinkage in weight of potatoes held at 40 degrees was greater than those held at 36, 50, 60, or 70 degrees. This is true for both skinned and non-skinned potatoes. The progressive percentage loss in weight of the skinned tubers varied from more than two to seven times the loss in weight of the non-skinned tubers.

The shrinkage of the skinned tubers held at 50 degrees F was approximately twice that of the non-skinned potatoes. But the progressive percentage losses of those held at 50 degrees were greater than those stored at 60 and 70 degrees.

There was very little difference in the shrinkage of both the skinned and non-skinned potatoes held at 60 and 70 degrees F. These losses were small in comparison with those stored at the lower temperatures. The chief disadvantage in storing potatoes at these higher temperatures is that these storage conditions are favorable for growth, and sprouting will occur when the rest period is over. Wright and Peacock (9) have found that the time varies at which potatoes will sprout when stored at 40, 50, 60, and 70 degrees F.

The authors found that the objectionable feature of sprouting of the tubers after the dormant period was over at 50, 60, and 70 degrees F could be overcome by gradually lowering the storage temperature just before the end of the dormant or rest period. A gradual change from a high to a low storage temperature was found to be better than a sudden one which is likely to "shock" the tubers and cause other injury. The potatoes stored at 36 degrees remain perfectly dormant after the rest period is over while those held at 40 degrees sprout very slowly, and seldom the sprouts are more than a quarter of an inch long by the middle of May. This is not objectionable in seed stock at that time of planting. The highest temperature at which potatoes will not sprout has not been determined. It may be found that potatoes will not sprout at 38 degrees F.

This method of storing potatoes greatly reduced the loss in weight of both skinned and non-skinned potatoes. The reduction in shrinkage, of course, was greater for the skinned tubers than the non-skinned potatoes.

The new skin periderm formed on the potatoes held at 50, 60, and 70 degrees F had the natural color of the skin of the Irish Cobbler variety. After the old skin which was still attached to the edges of the skinned areas had been removed, close observation was necessary to detect where the tubers had been skinned. The skinned areas on the tubers held at the lower temperatures were dark in color, shrunken, and more or less shriveled around the wound. Thus, there was not only a greater loss in weight of potatoes stored at the lower temperatures, but the salable quality, based on appearance, had been lowered.

The authors also have found the temperatures of 50, 60, and 70

degrees F to be better than 32, 36, and 40 for both the storage of table (8) and seed* stock.

In cutting the seed potatoes held at 32, 36, and 40 degrees, it was noted that they were more watery, coarser grained, and darker in color indicating that there was less starch and more free water than in those held at the higher temperatures.

Conclusions

The shrinkage of the skinned tubers varied from 1.8 per cent at 60 degrees to 16.3 per cent at 32 degrees and the non-injured potatoes from 1.8 to 5.1 per cent, respectively, at these temperatures by the end of the 12-week period. The shrinkage of the potatoes stored at 70 degrees F was slightly greater than at 60 degrees. Large shrinkage losses were controlled by storing the potatoes at the higher temperatures until about the end of the rest period and then gradually reducing the temperature sufficiently to prevent sprouting. Storage temperatures of 40 degrees and below prevented normal wound periderm formation, and the skinned areas soon formed a dark brown or black scab. Storage temperatures of 40 degrees F and below decreased the culinary quality of table stock and reduced the yield from seed potatoes. The effects of low storage temperatures can be detected by the more watery, coarser grained, and darker texture of the cut potatoes.

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*Unpublished data by the writers.

A Further Study of the Relation of Whole vs. Cut Roots to Sprout Production in the Sweet Potato

By J. H. Beattie and Ross C. Thompson, *U. S. Department of Agriculture, Washington, D. C.*

In a previous paper (1) the writers pointed out that the sweet potato possessed a marked dominance of the proximal end of the enlarged edible root in the production of draws or sprouts, and the limited data presented showed that cutting the roots into two or more pieces increased the number of sprouts from each sweet potato. It was suggested that the increase of sprouts by this treatment might be of some practical importance. This paper is a report of further investigations. The data include records of two experiments conducted in the greenhouse at Arlington Farm, Virginia, during the winter of 1931–1932; also an experiment carried on in hotbeds at Beltsville, Maryland, during the spring of 1932.

Methods and Materials

It is not always an easy matter to differentiate between the proximal and distal ends of a sweet potato after it has been severed from the hill. The material used in the experiments discussed in this paper was therefore selected in the field and the proximal end of each sweet potato marked with an indelible pencil as it was

TABLE I—Effect of Cutting Sweet Potato Roots on Plant Production (Winter 1931-1932)

No. Roots	Root Treatment	Mean Weight of Roots Bedded	Mean Number of Plants per Root
43	Whole, untreated	342.65±12.77	13.81±.068
40	2 pieces, formalin	275.23± 8.54	15.93±.052
43	2 pieces, semesan	323.97±10.89	16.95±.057
41	2 pieces, $HgCl_2$	310.60± 9.10	13.51±.044
38	2 pieces, untreated	303.52±10.88	17.66±.070
37	3 pieces, untreated	320.86±10.10	23.89±.073
46	Proximal end removed	296.34± 7.76	10.67±.038

No. Roots	Root Treatment	Mean Wt. Root per Plant (Gm.)	Coef. of Odds	Mean Wt. Plant (Gms)	Coef. of Odds*	Gm. Root per Gm. Plant
40	2 pieces formalin	17.28±.54	7.0			3.28±.28
43	Whole untreated	24.81±.93				
43	2 pieces semesan	19.11±.65	5.0			
41	2 pieces $HgCl_2$	22.89±.68	1.66			
43	Whole untreated	24.81±.93				
38	2 pieces untreated	17.19±.62	6.80			
37	3 pieces untreated	13.43±.42	11.16	5.55±.78	2.06	
43	Whole untreated	24.81±.93		7.56±.58		
46	Proximal end removed	27.77±.77	2.47	7.79±.52	.30	3.00±.06
162	All 2-piece lots	18.99±.48	5.34	6.34±.13	2.05	
43	Whole untreated	24.81±.93		7.56±.58		

*Differences are considered significant if the coefficient of odds is greater than 3.0.

removed from the hill. One lot of 20 bushels of Porto Rico sweet potatoes was selected at Florence, South Carolina, marked, packed in bushel baskets, shipped to Arlington Farm, Virginia, by express, stored for about 2 weeks without curing, and used in the first experiment started on December 9.

The work was conducted in a greenhouse fitted with raised benches filled with 8 inches of washed river sand. The sweet potatoes or portions of sweet potatoes were placed in rows across the bed, each one having approximately the same amount of space. The bedding was in accordance with customary practices, the sweet potatoes being shoved into the sand and then covered about an inch deep.

The various lots included in this experiment were bedded on December 9, 1931. All plants resulting were harvested, counted, and the total weight of plants per root or piece recorded, on January 29, February 23, and March 21, 1932. In the tabular summaries with analyses presented in Table I the data for the three harvestings are combined.

TABLE II—EFFECT OF VARIOUS TREATMENTS OF SWEET POTATO ROOTS ON PLANT PRODUCTION (SPRING 1932)

No. Roots	Root Treatment	Mean Wt. of Roots Bedded	Mean Number of Plants per Root
48	Whole, untreated	277.18± 8.44	22.50±.580
46	2 pieces, untreated	249.53± 6.13	30.88±.920
48	Whole, $HgCl_2$	246.81± 7.29	18.56±.494
48	Proximal end removed, $HgCl_2$	231.87± 6.39	15.29±.480
48	2 pieces, $HgCl_2$	252.81±13.66	27.43±.791
48	3 pieces, $HgCl_2$	271.06± 9.66	29.97±.716
47	Whole, formalin	239.25± 7.23	20.65±.498
48	Proximal end removed, formalin	229.47± 7.70	18.54±.600
48	2 pieces, formalin	228.95± 7.42	25.45±.541
48	3 pieces, formalin	286.14±10.76	34.16±.806
48	Whole, semesan	267.58± 6.49	17.37±.532
48	Proximal end removed, semesan	210.58± 6.05	10.77±.260
48	2 pieces, semesan	221.91± 6.77	23.04±.590
48	3 pieces, semesan	301.04± 9.07	30.54±.922

No. Roots	Root Treatment	Mean Wt. Root per Plant (Gms)	Coef. of Odds*	Mean Wt. Plant (Gms)	Coef. of Odds*	Gm. Root per Gm Plant
144	All roots with the proximal ends removed	15.07±1.58	.99	5.20±.72	.62	2.90±1.15
191	All whole roots	13.09±1.23		5.76±.54		2.27± .302
189½	All 2-piece lots	8.95± .160	3.13	4.30±.083	1.55	2.08± .040
191	All whole roots	13.09±1.23	3.25	5.76±.54	2.55	2.27± .302
143	All 3-piece lots combined	9.06± .163		4.38±.069		2.06± .049

*Differences are considered significant if the coefficient of odds is greater than 3.0.

The stock used in the second experiment was grown at Beltsville, Maryland. It was selected and marked in the field as was the case with the material for the first experiment and transported to the sweet potato storage house at Arlington Farm, Virginia, cured at 85 degrees F, and later stored at 55 degrees until February 25, when the experiment was started. The stock used in the first experiment was not cured. Details of bedding and general procedure were similar to the first experiment. The plants were harvested, counted, and weighed on April 1, April 25, and June 14. Records from all three harvestings are combined in the data given in Table II.

Discussion of the Two Experiments

The results of the two experiments are in general quite similar. The chemical treatments given the stock apparently had no effect on the sprout production. The roots used in the first experiment averaged larger than those of the second experiment, as indicated by the mean weights given in the first part of Tables I and II.

The various treatments within the two experiments gave comparable results. The mean weight of root per plant, mean weight of plant, and grams of root per gram of plant all ran slightly higher in the first experiment than in the second. Some of the differences between Experiment I and Experiment II can very likely be attributed to environmental conditions during the periods of the two experiments. The first experiment, started December 9 and ended March 21, was conducted during a period of short days and low light intensity. The second experiment, started February 25 and ending June 14, was more favorable for growth of the sweet potato plant as the length of day and light intensity were greater. Mean temperatures were also somewhat higher, and maximum temperatures were considerably higher on bright days.

TABLE III—The Number and Size of Plants Produced from Jumbo, Number 1, and String-Sized Sweet Potatoes. Bedded Whole With the Proximal End Removed and Cut in Pieces

Number Roots Bedded	Wt. Roots (Pounds)	Number Plants	Total Wt. of Plants (Gms)	Mean Wt. of Plants (Gms)
			Jumbo whole	
108	100	2,997	14,288.4	4.76
			Jumbo prox. end removed	
98	100	2,986	15,649.2	5.24
			Jumbo cut in two pieces	
95	100	2,373	10,750.3	4.53
			No. 1 Whole	
205	100	3,848	18,484.2	4.80
			No. 1 proximal end removed	
191	100	3,136	14,574.1	4.64
			No. 1 cut two pieces	
193	100	3,928	17,817.4	4.53
			Strings whole	
477	100	4,800	19,686.2	4.10
			Strings proximal end removed	
485	100	4,369	19,817.7	4.53

In order to obtain information on some of these relations under practical conditions an experiment was conducted at Beltsville, Maryland, during the spring of 1932. The material employed in this study was from the same source as that used in the second experiment. During the period between April 15 and 18, 300-pound lots of jumbo, Number 1, and string-size potatoes were selected and transported to Beltsville, Maryland, where they were cut or otherwise treated as indicated in Table III, then given the customary dip in formalin solution, and bedded on April 19 in a hot-water heated hotbed with the pipes buried in the soil about 10 inches below the surface. The temperature was maintained at 75 to 85 degrees during the plant-growing period until May 23, when the sweet potatoes were lifted, the plants removed, counted, and weighed. The results are shown in Table III.

Discussion of Results Obtained in Hotbed Test

The number of plants from 100 pounds of jumbo size seed stock was practically the same for the whole sweet potatoes and for those with the proximal end removed. The small yield of plants from the cut jumbos is due to the fact that 42 halves rotted and gave no yield.

With Number 1 seed stock the 100 pounds of whole sweet potatoes yielded 3848 plants against 2997 for the jumbo size. Those with the proximal end removed yielded only 3136 but there were a large number of decayed roots which yielded nothing. Number 1 stock cut in two pieces yielded more than the whole stock despite the fact that 41 halves decayed giving no yield. Strings bedded whole and with the proximal ends removed yielded more plants than were obtained from the same amount of seed stock of any larger size but the stock with the proximal ends removed yielded fewer plants than was the case with the whole sweet potatoes. Here also decay due to cutting had an important effect. The table also indicates that the fewer the plants the larger their size but this cannot be proved from these data which are of such a nature that the odds of significance can not be determined. Practically, this experiment indicates that strings are most economical for the growing of sweet potato plants provided that numbers alone are of importance. The writers urge caution in adopting this idea without knowing that a slightly smaller plant is as good as a larger one and that the size of the seed stock has no effect on the vitality and productive ability of the plant.

Conclusions

The dominance of the proximal over the distal end of the sweet potato in the production of plants can be broken by cutting them into two or more approximately equal portions and each of these sections has a distinct proximal dominance in sprout growth. Cutting of the sweet potato increases the number of plants but reduces their size. Whether small plants are as productive as large

ones is not shown. Removal of the proximal tip only of the sweet potato does not appreciably affect the dominance of the proximal end of the organ or influence the total number of plants produced. Under practical plant growing conditions in hot water heated hotbeds small sized seed stock produced the most plants. In the treatments used in these experiments decay of cut sweet potatoes was found to be a serious factor which might more than offset any advantage obtained by cutting.

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Carbon Dioxide Storage v. The Influence of Carbon Dioxide on Breaking Dormancy of Potatoes

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Abstract

The complete paper will appear in the Contributions from the Boyce Thompson Institute.

TREATMENT of dormant potato tubers (*Solanum tuberosum* L.), varieties Irish Cobbler and Bliss Triumph, with 40 to 70 per cent carbon dioxide and 20 per cent oxygen for 3 to 7 days brought about an increase in the rate of respiration and changes in the properties of the expressed juice and in the sprouting of the tubers. The respiration rate, as measured by the uptake of oxygen in the presence of 59 per cent CO_2, increased from 85 to 134 per cent over the control. Studies made on the expressed juice showed that the pH of the juice of treated tubers was increased about 0.6 to 0.7 of a pH unit. The rate of reduction of methylene blue by the juice of the treated tubers was increased, the time required for decoloration being from 3 to 10 minutes as compared to more than 30 minutes for the control. This change was not a result of the pH difference since it occurred after the juices were brought to the same pH value either with N/10 NaOH or N/10 HCl. There was an increase in the power of the juice to reduce iodine in acid solution. The sodium nitroprusside test indicated a higher sulphydryl content in the juice from the treated tubers. Analyses of the treated tubers at the end of the carbon dioxide treatment showed a low glutathione content, but further analyses 6 days after planting gave a decided increase over the control. Dormant potato tubers treated for 3 to 7 days with 40 to 70 per cent carbon dioxide sprouted and required from 19 to 35 days for 50 per cent to appear above ground as compared with 60 or more days for the control.

Effect of Fertilizer Treatment on the Shape of Porto Rico Sweet Potato

By R. L. Carolus, *Virginia Truck Experiment Station, Norfolk, Va.*

SWEET potato fertilizer studies have been conducted by the Virginia Truck Experiment Station at its Eastern Shore branch, on plats receiving the same continuous treatments over a thirteen year period. Zimmerley (4) in 1929 described the plat arrangement and fertilizer treatments applied and reported 9 years' results on the effect of fertilizer treatment on the yield of the Big Stem Jersey variety. During the past 4 years the Porto Rico variety has been grown on these plats under the same conditions as outlined by Zimmerley for the Big Stem Jersey variety. This paper presents in statistical form the results of some measurements made on roots from these variously fertilized plats in 1932.

The roots from 50 plants, spaced 15 inches apart in rows 30 inches apart and harvested during the second week in October, were used in making all measurements. Only roots of commercial value weighing between 100 and 750 grams were utilized in this work. The length was determined on that portion of the root that was larger than 1 centimeter in diameter. The maximum diameter was found by determining the largest hole in a series of circular holes with ½ centimeter diameter variations, through which the root failed to pass. This method resulted in a positive variation between the determined and actual diameter of less than 0.5 centimeters. Figures for the root weight were recorded to the nearest 5 grams.

All figures in Tables I and II are means with probable errors of roots from 50 hills, grown during 1932 under adverse climatic conditions due to lack of rainfall. The Length/Diameter ratio was calculated for each treatment and is considered as the index of shape. A large ratio indicates a relatively long potato, and a small figure denotes a relatively thick chunky root.

In Table I the effect of each fertilizer mixture is shown, arranged in order of the decreasing value of the Length/Diameter ratio. There is apparently no consistent relationship between fertilizer treatment and shape of roots. The five lowest Length/Diameter ratios, indicating a chunky type of root, were obtained from roots grown on areas treated with 3, 6, 9, and 12 per cent ammonia; 3, 6, 9, and 12 per cent phosphoric acid; and 3, and 6 per cent potash. This would indicate that low potash content in the fertilizer was conducive to the production of a short thick type of root, and were it not for the fact that low potash content also occurs in the fertilizer mixtures which produced roots with a high Length/Diameter ratio. The high potash to low nitrogen ratios (3–3–15) (3–6–12) produced a relatively long type of root. This lack of chunkiness of roots of the Porto Rico variety grown on plats treated with large percentages of potash is exactly opposite

to the finding of Schermerhorn (3) in regard to the effect of nutrients on the shape of the Yellow Jersey variety. He found that on plats fertilized according to the triangulation system, by increasing the amounts of potassium in the mixture and decreasing the amounts of nitrogen the shape of the root was influenced in the direction of increased chunkiness. The Length/Diameter ratio calculated from Schermerhorn's data (3) ranged from 4.2 where no potash was applied to 2.47 where an 8 per cent potash fertilizer was used. The average Length/Diameter ratio, 2.47, of his chunkiest group was practically the same as the ratio 2.43 of the longest group in Table I. Apparently the shape of the Porto Rico variety has normally a low Length/Diameter ratio and is less readily influenced by nutrient conditions than is that of the Yellow Jersey variety.

TABLE I—ROOT SHAPE IN THE PORTO RICO SWEET POTATO ARRANGED ACCORDING TO THE DESCENDING ORDER OF THE LENGTH/DIAMETER RATIO

Fertilizer	Ratio L/D	Diameter (Cms)	Length (Cms)	Weight (Gms)	No. of Roots per Hill
3-15- 3	2.43±.081	6.06±.128	13.99±.370	216± 7.42	1.86±.115
3- 9- 9	2.40±.069	6.53±.138	14.60±.303	255±11.40	1.95±.101
12- 6- 3	2.40±.055	6.65±.101	15.22±.290	263± 9.87	1.91±.121
3- 3-15	2.36±.041	6.27±.108	14.39±.283	243± 9.03	1.91±.115
3- 6-12	2.30±.062	6.53±.138	14.09±.263	248±12.88	2.37±.128
15- 3- 3	2.29±.066	6.41±.148	13.95±.317	243±10.78	1.95±.101
5- 8- 5	2.21±.051	6.59±.112	13.91±.248	243± 8.60	2.24±.109
6- 6- 9	2.21±.049	6.45±.101	12.71±.421	260± 8.84	2.48±.175
6- 3-12	2.20±.063	6.71±.128	14.13±.317	282±11.74	2.48±.162
6- 9- 6	2.19±.054	6.46±.115	13.56±.256	254± 8.77	2.33±.121
9- 3- 9	2.15±.061	6.82±.128	13.92±.296	279±11.53	2.02±.128
6-12- 3	2.15±.045	6.34±.094	13.32±.263	242± 8.30	2.51±.142
12- 3- 6	2.12±.056	6.64±.101	13.40±.290	256±10.78	2.27±.128
9- 9- 3	2.08±.048	7.12±.088	14.32±.276	289±10.18	2.36±.115
3-12- 6	2.08±.039	6.48±.108	13.00±.222	235± 8.70	2.41±.128
9- 6- 6	2.04±.057	6.97±.121	13.46±.276	279±10.79	2.43±.155

A further critical study of the Length/Diameter ratio is presented in Table II. The significance of differences in the Length/Diameter ratios found in roots grown on plats fertilized with varying amounts of potassium as compared with nitrogen are given in terms of odds. No consistent significant differences, indicating the superiority of one fertilizer mixture over another in the production of the short thick type of sweet potato root were found. However, some trends in the significance are worthy of note. Large amounts of any one element in the fertilizer mixture, as shown by the first two differences of each series, did not give significant differences. This may indicate that shape is not influenced by a large amount of any one element when there is a comparative scarcity of the other two. Odds of 54:1 as to the reliability of the significance of a difference of .32 ± .09 in the Length/Diameter ratio between the 3-9-9 and the 9-9-3 treatments indicate that nitrogen in the

TABLE II—THE RELATION OF THE INGREDIENTS IN THE FERTILIZER MIXTURE TO THE LENGTH/DIAMETER RATIO

Potassium Compared with Nitrogen			Potassium Compared with Phosphorus			Phosphorus Compared with Nitrogen		
Fertilizer	Difference of L/D Ratios	Significance of Difference in Odds	Fertilizer	Difference of L/D Ratios	Significance of Difference in Odds	Fertilizer	Difference of L/D Ratios	Significance of Difference in Odds
3- 3-15	2.36±.041		3- 3-15	2.36±.041		3-15- 3	2.43±.081	
15- 3- 3	2.29±.066		3-15- 3	2.43±.081		15- 3- 3	2.29±.066	
	+.07±.08*	<1:1		—.07±.09†	<1:1		+.14±.11‡	1.6:1
3- 6-12	2.30±.062		6- 3-12	2.20±.063		3-12- 6	2.08±.039	
12- 6- 3	2.40±.055		6-12- 3	2.15±.045		12- 3- 6	2.12±.056	
	—.10±.08	1.4:1		+.05±.08	<1:1		—.04±.07	<1:1
3- 9- 9	2.40±.069		9- 3- 9	2.15±.061		3- 9- 9	2.40±.069	
9- 9- 3	2.08±.048		9- 9- 3	2.08±.048		9- 3- 9	2.15±.061	
	+.32±.09	54:1		+.07±.08	<1:1		+.25±.09	16:1
3-12- 6	2.08±.039		12- 3- 6	2.12±.056		3- 6-12	2.30±.062	
6-12- 3	2.15±.045		12- 6- 3	2.40±.055		6- 3-12	2.20±.063	
	—.07±.06	1.2:1		—.28±.08	54:1		+.10±.06	3:1

*Positive differences are in favor of potassium. Negative differences are in favor of nitrogen.
†Positive differences are in favor of potassium. Negative differences are in favor of phosphorus.
‡Positive differences are in favor of phosphorus. Negative differences are in favor of nitrogen.

presence of 9 per cent phosphoric acid is more conducive to the formation of the chunky type root than is potash. Odds of 54:1 as to the reliability of the significance of a difference of — .28 ± .08 in the Length/Diameter ratio between the 12–3–6 and the 12–6–3 treatments may indicate that potassium in the presence of 12 per cent nitrogen is more effective in the production of the short, thick type of root than is phosphoric acid.

The work of Robbins (2) and Nightingale (1) showing that both nitrogen and potassium were needed to accelerate cell division in the direction of diameter and thereby cause chunkiness, may partly explain the difference obtained in the two cases cited above. It is, however, possible that the significant differences in these two cases were merely due to undetermined environmental factors.

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The New Hampshire Budget Garden

By J. R. Hepler, *New Hampshire Experiment Station, Durham, N. H.*

THE farm garden has an average value of $52.00 per garden in the United States, with an aggregate total for all gardens which is almost as high as the commercial gardens. In New Hampshire with an average value of $70.00, it stands fourth in total value of crops, averaging 15 per cent higher than the commercial gardens. Even so the census figures for the home garden are undoubtedly very low.

The 11,000 farm gardens were grown by only about 10 per cent of the families living in New Hampshire. At least half of these families live in small towns and villages and many of them have backyard or community gardens, not included in the census figures. Probably the true value of the home garden industry would be almost twice the census figures or equal to that of the apple crop or the potato crop.

Despite the high total value of the home garden, very little was done to improve it, outside of a bulletin and occasional news articles. Since the cash income from the farm garden is of necessity negligible, both the farmer and the extension workers paid little attention to it and devoted their energies to those crops that brought in cash. However, the spread of insects and diseases and the unquestioned value of vegetables in the diet, have shown the necessity of more education about the home garden.

The New Hampshire budget garden is an attempt to improve the home garden, to supply the needs of the family for fresh, stored, and canned vegetables. The budget garden project is not limited to the farm garden but includes the small hand cultivated garden of the village as well. It is a coöperative project with the Home Demonstration Agents. They are chiefly interested in a better balanced diet from a greater variety of vegetables grown in the garden, especially those carrying vitamins and minerals. During the winter meetings the garden coöperators signify their intentions of taking the project. They are then visited by the Home Demonstration Agent who makes out their food and canning budget, on a special form, basing the requirements on those vegetables preferred by the family as far as possible, yet insisting on the full quota of green vegetables and tomatoes.

The requirements are based on the use of at least two vegetables daily, one of which is a green, in addition to potatoes. The estimated number of servings, including potatoes, is 1580 per year per person, each serving being based on ½ cup of canned vegetables, and ¼ pound of fresh vegetables. This would require approximately 555 pounds of vegetables for one person, of which 175 are eaten fresh out of the garden, 235 pounds are stored, and 145 pounds are canned. Of these, 120 pounds are green vegetables; 55,

tomatoes; 180, potatoes; and 200, all others including roots, peas, beans, corn, and the vine crops.

The vegetable budget is then sent to the central office where the feet of row for each vegetable, the amount of seed or plants needed, the time of planting, the distance between rows, and the number of plantings are filled in.

The value of this latter practice is questionable. It can only at best be a general estimate, it takes considerable time, and the recommendations are seldom followed very closely. In the future a printed table with all this information will be sent to each coöperator. However, intelligent planning to conserve labor and to make the best use of the land available are always emphasized. The use of horse and machine labor is urged when available; for hand cultivation a cheap wheel hoe is recommended in preference to the hand hoe.

During the summer a visit is paid each garden by the garden specialist, and improvements suggested or questions answered. The better gardens are usually visited during the county farm tour.

To save time, it is planned to have two garden meetings in the larger counties and one in the smaller counties, held at one of the better gardens. Various garden problems are then discussed. Even though a rather comprehensive garden bulletin is put in the hands of each coöperator, there are always many questions to answer. To supply this need in part, a series of mimeographed garden letters was sent to each coöperator. These letters were sent out at 2-week intervals during the period from February to June and covered the following topics: (1) Varieties to plant and source of seed, (2) soil preparation and fertilization, (3) growing greens and salad crops, (4) root crops, (5) growing peas, beans, tomatoes, and vine crops, (6) controlling common diseases and insects with special reference to home garden practices. Two additional letters were sent out in a few of the counties, one on growing rutabagas and the other on controlling cucumber scab.

These garden letters proved very popular. When they were suggested it was estimated that around 400 would be needed, yet a total of about 2000 were finally sent out from the county offices, all on request. Replies from 410 people, not budget garden coöperators that received these letters show that a total of 1093 practices were adopted. The suggestions on fertilizing and preparing the soil were used by 50 per cent, the information on peas, beans, and corn by 42 per cent, and those on insect and disease control by 43 per cent. No figures are available on the value of the list of varieties or the information on greens and salad crops.

The greatest change that the budget garden has made is in the kind of vegetables grown. The old-fashioned garden was planted mostly to corn, potatoes, beans, squash, cucumbers, with very little else. The budget garden emphasizes the green and salad vegetables and contains a much bigger variety. Canning statistics were obtained from 239 out of approximately 325 budget gardens in 1932.

The total number of quarts of vegetables canned was 29,125 or an average per family of 121.8 quarts, divided as: 38.2 quarts greens, 21.5 quarts tomatoes, 25.7 quarts pickles and relishes, and 36.3 quarts all other vegetables. These include peas, beans, corn, root crops, and others. These 239 gardens represented about 850 people including 371 children, or an average of 34.2 quarts per person. Budget recommendations call for 38.5 quarts of vegetables for each adult and half that amount for children. On this basis the required amount per person in the families listed is 29.3 quarts, or 4.9 quarts less than the actual amounts prepared.

In addition to the regular coöperators, some other gardeners were sent the garden letters. Reports from these show that a total of 35,963 quarts of vegetables were canned by 376 families, an average of 95.6 quarts per family, or 26.2 quarts less than the coöperators. The chief difference lay in the amount of greens which was 14.4 quarts less per family.

Numerous problems are encountered. Few of the home gardeners grow spinach successfully, probably less than 10 per cent. They are afraid to plant celery and not over 5 per cent even try to grow it. Onions, cabbage, and cauliflower are other crops not grown as much as they should. The chief insects are the maggots and green worms on cabbage, the Mexican bean beetle, the bean weevil, the cucumber beetle, the squash bug, the flea beetle, tomato worm, and leaf hoppers. The two most troublesome diseases are root rot of peas and cucumber scab.

In fact, the culture of peas and cucumbers has been abandoned in many gardens because the garden plot is so badly infected. Rotation is not always feasible because of lack of land and prevalence of witch grass. Fusarium and wilt on squash, wilt on cucumbers, alternaria on tomatoes, and club foot on crucifers also cause difficulty.

Dusting is recommended for the home garden in preference to spraying because of better coverage by inexperienced operators. The 20–80 monohydrate copper sulfate-lime dust is recommended for leaf diseases; a 10–15 per cent lead or calcium arsenate dust for chewing insects; in combinations, 8 per cent lead arsenate and 72 per cent lime in place of the 80 per cent lime; and nicotine dust for aphids. It is useless to recommend a dusting or spraying material that cannot be bought at the grocery or hardware store. Calcium fluosilicate dust, for example, has been recommended for cucumber beetles but is not used because the local dealers do not carry it.

Effects of Bulb Shape and Weight on the Number of Seed Stalks of the Sweet Spanish Onion

By A. M. Binkley, *Colorado Agricultural College, Fort Collins, Colo.*

THE results of a 3-year study of mother bulb weight in relation to shape and the number of seed stalks formed, are presented as a preliminary report on a phase of improvement of the Sweet Spanish onion.

This variety is considered a relatively light seed yielder in Colorado. The question of whether a large bulb will produce more seed stalks than a small one is of considerable importance. The association of the characters, weight and width of bulb and weight and length of bulb, was also studied.

Approximately 400 bulbs of the Riverside strain from the same seed source were measured and weighed each year. The bulbs were grown under the same soil conditions each year, and they were taken field-run, or without selection down the row.

Each bulb was weighed, measured for polar and equatorial lengths, numbered, and set out in the field. The average of two caliper measurements was taken to correct for bulbs not symmetrical in shape. The number of seed stalks formed by each numbered bulb was counted as an indication of possible seed yield. The number of seed stalks ranged from 1 to as high as 15 stalks per bulb, with an average close to 5 stalks for the 3 years.

The correlation coefficient is used as a means of determining the extent to which the seed stalk character,is transmitted from mother bulbs of different size and shape. The association of bulb width and weight and bulb length and weight is also reported.

Results

The correlation study summarized in Table I indicates that a wide, flat mother bulb, under Colorado conditions, will not produce more

TABLE I—Summary of Correlation Coefficients

Bulb	Between Mother Bulb and Seed Stalks Formed			Between Weight and Width and Length	
	Width	Length	Weight	Width	Length
1929	—0.21±0.03	—0.20±0.04	—0.25±0.03	0.85±0.01	0.74±0.02
1930	—0.94±0.03	—0.17±0.03	—0.17±0.03	0.94±0.02	0.65±0.02
1931	—0.29±0.03	—0.12±0.03	—0.13±0.03	0.92±0.004	0.74±0.02

seed stalks than a long or round bulb. For polar length measurements the caliper points were placed at the base of the neck and side of the root scar.

The correlation results between length of mother bulb and number of seed stalks formed indicate no definite relationship between length of mother bulb and number of seed stalks produced.

In the weight studies, the bulbs used were taken without selection from the field. The weight range for individual bulbs during the 3 years varied between 75 and 802 grams per bulb. The class intervals are 28.35 grams. The classes of greatest frequency for the 3-year period varied between 310 and 338 grams in 1929, 339 and 367 grams in 1930, and 281 and 309 grams in 1931.

The correlation of weight and number of seed stalks formed is not significant enough to definitely associate the two factors. A small bulb of 75 grams weight is apparently capable of producing as many seed stalks as one of 800 grams, if it is grown under favorable conditions and has the same genetic constitution.

Lack of significant correlation does not mean that it would always be practical to save small bulbs for seed production. In selecting bulbs for seed improvement, the small bulbs are more often round and of ideal shape than large bulbs. It apparently requires considerable size for bulbs to express their true shape. Small bulbs, while capable of producing as many seed stalks as large bulbs, cannot go through as long periods of drought early in the spring because of a smaller quantity of stored food in the bulb.

The relation of bulb length to weight is definitely associated as indicated by the correlation coefficient.

The polar length for the 3 years averaged 7.5 to 8.5 cm, the range varying between 5.5 and 12.0 cm, and the classes of greatest frequency for weight varied between 281 and 367 grams. There is a definite relationship between length of bulb and weight within the range of polar length measurements recorded.

The association of the factors equatorial length and weight of bulb is the most significant factor studied, especially for 1931. Apparently the more round a bulb is the closer the association of weight becomes to the width and length.

Summary

1. There was no significant positive correlation between the number of seed stalks formed, and the length, width or weight of the mother bulbs under the conditions of these experiments. A mother bulb, light in weight, is capable of producing, under favorable conditions, as many seed stalks as a large, heavy one. A wide, flat mother bulb will not produce any more seed stalks than a long, deep one.

2. There was a significant positive correlation between length of onion bulbs and weight, and a more significant positive correlation between width of onion bulbs and weight.

Factors Affecting Flowering and Fruit Setting in the Pepper

By H. L. Cochran,[1] *Cornell University, Ithaca, N. Y.*

MANY growers experience difficulty in raising peppers during certain years because of the fact that a large percentage of the flowers and young fruits drop. In other years flowering and fruit setting are normal. The object of the experiment reported here was to study effects of temperature, length of photoperiod, soil moisture, and soil nitrate supply on flowering and setting of fruit in the pepper.

Seeds were planted in flats in a good greenhouse soil on October 16, 1931. On November 26, all plants were shifted to 8-inch clay pots, one plant to the pot, containing 9 pounds of soil (wet weight) known to be fairly low in nitrates. Muriate of potash at the rate of 500 and superphosphate at the rate of 2500 pounds to the acre was worked into the soil. The plants were placed in a warm greenhouse (70–80 degrees F) and kept well watered for 14 days, to insure root replacement.

On December 5, the experimental treatments were started, with 40 plants in each of three greenhouses, warm (70–80 degrees F), medium (60–70 degrees F) and cool (50–60 degrees F). Twenty plants in each house were grown under the normal length of day and 20 under long-day conditions. The long-day plants were grown under electric lights from 5 to 10 P. M. Artificial light was supplied by 75-watt Mazda bulbs suspended 24 inches above the plants and 24 inches apart. The 20 plants under each temperature and light conditions were divided into four lots of five plants each as follows: (A) high nitrate, high moisture; (B) high nitrate, low moisture; (C) low nitrate, high moisture; and (D) low nitrate, low moisture.

For the high-moisture treatment sufficient tap water was added each day to keep the soil wet, but not saturated, while for the low-moisture treatment just enough water was added to keep the plants from wilting.

In the high-nitrate treatment the soil was watered once each week with a solution containing 1 ounce of nitrate of soda to 1 gallon of water. No nitrate was applied to the soil of the low-nitrate treatment.

Results

Daily observations were made and records taken on the number of flowers that opened and likewise the number that dropped. Each flower was tagged, showing the date of anthesis and if it did not drop within 15 days it was classed as having set. The results of the treatments on flowering and fruit setting are shown in Table I. It is

[1]The writer wishes to express his appreciation to Dr. H. C. Thompson, under whose direction this work was conducted.

evident that plants grown in the warm greenhouse produced a larger total number of flowers than did those in the medium house and likewise a larger total number of flowers dropped under the former than under the latter. Plants grown in the cool house produced only one weak flower and it dropped. Plants subjected to the medium-temperature treatment produced flowers with larger pedicels than those in the warm house, which in all cases but one, was associated with higher percentages of fruit-set. The coefficient of correlation between pedicel diameter and percentage of flowers that set fruit was 0.290.

It is also evident from the data in Table I that the length of photoperiod did not materially influence the total number of flowers that opened, but it did affect the total number and percentage that set fruit, and the size of pedicels. In both the medium and the warm house the

TABLE I—EFFECTS OF TEMPERATURE, PHOTOPERIOD, SOIL MOISTURE, AND SOIL NITRATE ON FLOWERING AND FRUIT SETTING IN THE PEPPER

Treatment	Number Flowers Opened	Number Flowers Dropped	Number Flowers Set Fruit	Per cent of Flowers that Set Fruit	Av. Diameter for 10 Pedicels (Mm)
			Warm House		
Long Day					
HN—HM	200	164	36	18.00	1.43±0.040
HN—LM	77	75	2	2.59	1.17±0.020
LN—HM	107	90	17	15.88	1.38±0.036
LN—LM	106	96	10	9.43	1.22±0.050
Total . ..	490	425	65	Ave. 13.26	
Normal Day					
HN—HM	273	189	84	30.76	1.48±0.033
HN—LM	43	31	12	27.90	1.23±0.021
LN—HM	133	95	38	28.57	1.66±0.026
LN—LM	45	29	16	35.55	1.20±0.016
Total	494	344	150	Ave. 30.36	
			Medium House		
Long Day					
HN—HM	98	58	40	40.81	1.59±0.020
HN—LM	33	24	9	27.27	1.59±0.030
LN—HM	64	42	22	34.37	1.51±0.024
LN—LM	37	25	12	32.43	1.41±0.020
Total........	232	149	83	Ave. 35.77	
Normal Day					
HN—HM	116	66	50	43.10	1.72±0.039
HN—LM	22	9	13	59.09	1.63±0.051
LN—HM	61	38	23	37.70	1.76±0.033
LN—LM	32	23	9	28.12	1.73±0.032
Total........	231	136	95	Ave. 41.12	

Cool House

Plants produced only 1 weak flower and it dropped

fruit-set was greater under the normal-day than under the long-day. The pedicel diameter was also greater under the normal-day in all treatments except the low-nitrate, low-moisture treatment in the warm house. Lengthening the photoperiod by 5 hours delayed the appearance of blossoms 15 days in the warm house and 19 days in the medium house. Auchter and Harley (1) found that peppers were not sensitive to light intensity, or length of daily illumination.

TABLE II—Effects of Temperature, Photoperiod, Soil Moisture, and Soil Nitrate on Plant Growth and Fruit Production in the Pepper

Treatment	Average Height of Plants (Cm)	No. Mature Fruits Picked*	Number Immature Fruits Picked†	Total Weight of Mature Fruits (Gms)	Average Weight of Mature Fruits (Gms)
			Warm House		
Long Day					
HN—HM	95.5	21	15	795.9	37.9
HN—LM	55.1	1	1	10.0	10.0
LN—HM	81.5	11	6	280.8	25.5
LN—LM	75.5	6	4	122.5	20.4
Total.. ..	—	39	26	1209.2	—
Normal Day					
HN—HM	66.2	37	47	893.3	24.1
HN—LM	39.6	5	9	65.9	13.1
LN—HM	49.0	15	23	259.8	17.3
LN—LM	38.2	7	9	76.8	10.9
Total....	—	64	88	1295.8	—
			Medium House		
Long Day					
HN—HM	66.5	36	4	762.8	21.1
HN—LM	40.0	6	3	47.4	7.9
LN—HM	51.9	13	9	203.5	15.6
LN—LM	51.8	12	0	138.1	11.5
Total.	—	67	16	1151.8	—
Normal Day					
HN—HM	45.4	34	16	612.3	18.0
HN—LM	24.5	8	5	72.6	9.0
LN—HM	36.3	18	5	278.5	15.4
LN—LM	36.3	6	3	86.7	14.4
Total......	—	66	29	1050.1	—
			Cool House		
Regardless of environmental factors, no plant exceeded 16 centimeters in height or produced any fruit					

*Fruits 30 days old from date blossom opened.
†Fruits 15 days old when experiment ended.

The combination of high nitrates and high soil moisture produced more flowers and a larger total number of fruits than did any other treatment. It also resulted in the highest percentage of fruit set

under long-day conditions, but not under the normal day. The high-nitrate, low-moisture treatments in the cool house resulted in the death of 8 of the 10 plants, due probably to the high concentration of the soil solution as growth was curtailed by the low temperature and an excess of nitrates accumulated. The plants with low-moisture treatment produced the smallest number of blossoms and fruits. This agrees with the results obtained by Smith (2) in his study of blossom drop of the tomato.

Effects of the various factors on plant growth and on the yield of fruit is shown in Table II. Vegetative growth was greater under the long-day than under the normal length of day in all cases. The plants in the warm house made considerably greater growth than did those under the same length of day in the medium house. Plants grown under high-nitrate, high-moisture treatments in both the warm and medium houses elongated much faster than did any of the others while plants in the cool house showed little difference between treatments. The quantity of fruit under the best treatment (high-nitrate, high-moisture) was higher under high temperature than under medium temperature. In the warm house the plants grown under the normal length of day produced more fruit than those grown under the long-day, while in the medium-temperature house the reverse was true.

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Influence of Fertilizer Treatment on Lettuce Head and Seed Production[1]

By L. L. Claypool, *State College of Washington, Pullman, Wash.*

In order to study some of the problems relating to lettuce fertilization, investigations were inaugurated by the Irrigation Branch Experiment Station of the State College of Washington at Prosser in 1930 on fine sandy loam soil.

The experimental field had been continually cropped since the removal of sage brush in 1919, and had produced alfalfa for the 3 years from 1919 to 1921 and Biennial White sweet clover in 1926 and 1927. Barnyard manure from alfalfa-fed animals was applied in the spring of years when the field was not in a legume crop, at the following rates of application per acre: 1922, 2 tons; 1923, 12 tons; 1925, 8 tons; 1929, 10 tons; and 1930, 12 tons.

Plots 15 by 100 feet were laid out in a duplicate series with the exception of phosphorus and potash alone where only one plot of each was used. The treatments included Check, N, P, K, NP, NK, PK, NPK, and manure. Every third plot was a check. Phosphorus and potash in the forms of treble-superphosphate and potassium sulphate respectively were applied annually at the rate of 160 pounds each of P_2O_5 and K_2O per acre. Nitrogen, as ammonium sulphate, was used at the rate of 120 pounds of N per acre in 1930 and 1931. In 1932 the rate was increased to 180 pounds of nitrogen. Twelve tons per acre of dry corral manure were used each year. Fertilizers were broadcast and plowed under to a depth of about six inches before planting.

Rows were 18 inches apart with plants about 15 inches apart in the row. Irrigation water was applied uniformly to all the plots and passed through one plot only. The four center rows, 80 feet long, of each plot were used for records, thereby allowing a 10-foot border on each end of the plot and a three-row border of plants receiving the same fertilizer treatment on each side of the record rows.

The New York variety of lettuce was grown in 1930. In 1931 and 1932 the New York No. 12 strain was grown on the plots.

Size and Firmness of Heads. The weight, relative firmness and the order in which maturity of heads was reached on the different fertilizer plots is shown in Table I.

In 1931, manure plots were the only ones to show appreciable benefits over the checks from fertilizer applications. However, nitrogen plots showed some improvement over check plots. Phosphorus and potash applied either alone or combined were not consistently beneficial.

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In 1932, when 180 pounds of nitrogen were used all plots receiving nitrogen showed a marked improvement over other plots. There was no measurable difference between Check, P, K, and PK plots. All of them failed to head, making only a weak growth and later shooting into seeders. Phosphorus was definitely beneficial when applied with nitrogen. The combination produced heads almost as large as those on manure plots. Potash applied with nitrogen seemed to increase the size of heads over that of nitrogen alone, but the results were inconclusive. When used in addition to NP potash gave no apparent benefits.

TABLE I—WEIGHT, RELATIVE FIRMNESS AND ORDER OF MATURITY OF HEADS ON LETTUCE FERTILIZER PLOTS

Treatment	Weight of Heads (Gms)		Relative Firmness		Order of Heading
	1931	1932	1931	1932	1932
Check ..	479	No heads	Soft	—	--
P. .	547	No heads	Soft	—	–
K .	467	No heads	Soft	—	–
PK ..	486	No heads	Soft	—	–
N.	523	529	Soft	Firm	3
NK	454	613	Soft	Soft-firm	4
NP ..	579	745	Soft-firm	Very firm	2
NPK	503	770	Soft	Very firm	2
Manure .	624	789	Firm	Very firm	1

In 1932 manure plots produced the firmest heads, but plots receiving NP or NPK were almost as firm. Nitrogen plots did not produce very hard heads, but they were firmer than heads from NK plots.

A positive correlation was found to exist between earliness of maturity and firmness of head. All plots to which NP combined was applied, whether as NP, NPK or manure, matured earlier than plots receiving N or NK.

Seed Production. In 1931 and 1932 the plants were allowed to seed after the desired records had been taken regarding heading and maturity. In 1930 the plants had reached the stage of apparent maximum seed production on August 22 when delay in harvesting might result in considerable loss of seed by shattering. At this time 100 representative plants were harvested from the center of each plot for yield records.

Table II shows the yield and size of seed for all plots in 1932 except where P and K were used alone. Records from the P and K plots are not presented because the plants together with those from one check plot were mixed up by a whirlwind and although there was little difference in the yields of these three plots, an attempt to present their data would be inaccurate.

All fertilized plots shown in the table produced an increased yield of seed over the check plots. Plots receiving nitrogen alone or in combination with phosphorus and potassium gave greatest increases in yield. Phosphorus applied with nitrogen increased the yield over

nitrogen alone whether as NP, NPK or manure. Potassium applied with nitrogen gave increases over nitrogen alone, but when applied with NP no appreciable yield increases over NP alone were obtained. Lettuce plants receiving NP produced the largest sized seed. Seed from plants on plots receiving NK was about the same size, determined by weight, as that from N plots, whereas seed from plots to which no nitrogen was applied was considerably smaller.

TABLE II—Yield and Size of Seed from Lettuce Fertilizer Plots

Plot	Treatment	Yield of Seed from 100 Plants (Gms)	Yield of Seed (Lbs. per A.)	Size of Seed
				Weight of 1000 Seeds (Gms)
4	N	1,484	760	1.0510
5	Check	800	410	.9226
6	N P	2,244	1,149	1.0730
7	N K	2,352	1,205	1.0366
8	Check	554	285	.8524
9	N P K	2,372	1,219	1.0760
10	P K	932	479	.9218
11	Check	516	265	.8924
12	Manure	2,840	1,460	1.0474
13	N	1,320	678	1.0090
14	Check	1,024	526	.9470
15	N P K	2,224	1,143	1.0670
16	N P	2,270	1,167	1.1186
17	Check	616	317	.9298
18	P K	1,004	516	.9740
19	N K	1,812	931	.9832
20	Check	1,040	535	.9686
21	Manure	2,572	1,322	1.0414

Discussion

Nitrogen was apparently the chief limiting factor. Although plots receiving nitrogen alone responded greatly to the fertilizer application when compared with plots on which no nitrogen was used, they were not as good as plots where nitrogen was applied in combination with another element. Phosphorus seemed to be a second limit-factor and gave a considerable increase in yield when applied with nitrogen. An addition of potash to the combination of nitrogen and phosphorus apparently did not give any significant increased benefits in plant growth or yield of heads and seed, although when applied with nitrogen it seemed to stimulate growth but not heading.

In this particular soil, nitrogen, which was the chief factor limiting soil fertility, was also the chief factor in influencing the size and yield of seed. Phosphorus was not only the second limiting factor in soil fertility, but also in seed development. Additions of potassium to the soil were of no apparent benefit in seed development. Increases in the yield of seed on plots receiving nitrogen alone or in combination with phosphorus and potassium over all other plots were not entirely

due to the production of larger seed. The number of flowers formed on plants in the different plots was of considerable more importance. There was a positive correlation between the size of heads and the number of flowers produced on the seed stalk. This indicates that the nitrogen supply probably increased the number of flowers by its effect in producing a large leaf area which in turn stored up large quantities of carbohydrate material thereby aiding flower bud formation and development. These results indicate that whatever element is limiting, its addition will have a direct influence in hastening maturity and in increasing the size of head and yield and size of seed. Nitrogen, applied alone in the amounts employed, did not delay maturity. However, when both the deficient elements of nitrogen and phosphorus were applied together maturity was hastened.

The Effect of Certain Mineral Elements on the Color and Thickness of Onion Scales

By J. E. KNOTT, *Cornell University, Ithaca, N. Y.*

ABSTRACT

The complete paper will appear as Bulletin No. 552 of the Cornell University Agricultural Experiment Station.

ONIONS grown on some muck soils in New York have thin scales of poor color. Well-bred varieties of onions, planted on mucks normally producing onions of poor or of good color, developed scale characteristics typical of the muck soil on which they were planted, indicating that the unsatisfactory scale condition is due largely to environment. Greenhouse and field studies showed that this condition could be overcome by the use of superphosphate or of copper sulfate. The latter appears to be the better treatment. An application of 200 to 300 pounds of powdered copper sulfate (bluestone) to an acre is recommended on muck which produces onions with thin, poorly-colored scales, or thin scales of fair color.

The Effect of Kind of Paper Bags on the Production of Selfed Table Beet Seed under Bags

By Roy Magruder, *U. S. Department of Agriculture, Washington, D. C.*

SATISFACTORY results from the limited use of Kraft paper bags as isolation material for the production of selfed beet seed in 1930 (1) led to a more comprehensive test of their value in comparison with glassine and parchment paper bags. The present paper is a brief report of the 1932 results as obtained at Arlington Farm, near Rosslyn, Virginia.

The mother beet roots were grown in 1931 from selfed seed. The original selections were made from the Detroit Dark Red variety of table or garden beets. Roots were removed from storage in March and transferred to a greenhouse bench where they started growth and remained until set in the field on May 3.

The bags were applied throughout the month of June as the inflorescences reached the proper stage. The tips of all branches to be covered were removed to limit the amount of growth within the bag and cotton was wrapped around the stem to prevent the entrance of insects. The mouths of the bags were closed about the cotton by tying tightly with soft cotton cord which was also used to tie the bags to a wire support placed over the row. To insure pollination the bags were shaken vigorously about noon each day during the blooming period.

Four types of bags were used. The brown Kraft bags were of the 10-pound size, square bottom and of the Tiger Kraft brand. One style of medium weight glassine bag measured 8 by 14 inches and the other 5½ by 12 inches when flat. A limited number of parchment paper bags, 4 by 2½ by 11¼ inches, were also used.

After the inflorescence within had turned brown, the intact bags were removed, numbered, and stored until such time as the counts could be made. In order to determine the efficiency of the different bags, the percentage of flower clusters that had set one or more seeds was calculated. Because of the labor required to make an accurate count of the flower clusters in each bag, only an approximation was obtained. A small portion of one branch was counted and from this an estimate of the total number was made and recorded. Every flower cluster containing one or more enlarged carpels was removed and counted as a seed, even though as judged by size alone there might have been a question in many cases as to whether it contained a viable embryo.

A portion of the seed from some selected families was space-planted in an irrigated garden but most of the germination tests were made in the greenhouse in muck soil. All of the seed up to a maximum of 50 from each bag was planted and the germination recorded separately.

In cases where the quantity of seed permitted, a greenhouse germination test was also made of those lots planted in the garden.

Results

The detailed data are too voluminous to be given even in a table and are briefly summarized below.

Only those plants that produced seed are considered in this report. The average number of Kraft bags per plant was 1.21, of 8 by 14 glassine 1.94, of 5½ by 12 glassine 2.13, and of parchment paper 1.26. Unfortunately, all four types of bags were not present on all plants.

For simplicity the percentage of seeds was used as an index for ranking the kind of bags. A total of 88 plants carried one or more Kraft bags and one or more of the other kinds of bags and in this number of comparisons the Kraft bags contained the greater percentage of seeds set, in 63 cases (71 per cent). In 12 comparisons it was second in rank and in 4 comparisons it was third in rank. In 9 cases the Kraft bags contained no seeds, whereas 1 or more of the other kinds of bags did contain seeds. Of particular interest, however, is the fact that of the 63 cases where the greatest percentage of seed set was in the Kraft bags, on 19 of the plants the Kraft bags were the only ones containing seeds. This indicates very clearly that the conditions within the Kraft bags were more favorable for the production of seed than in the glassine or parchment paper bags.

It has been shown previously (2) that the percentage of germination of seed produced under bags is usually very low so the germination tests provide the critical index of the relative value of the different kinds of paper bags. Since the germination percentage alone might be misleading as it does not take into account the number of seeds produced, it was thought advisable to calculate the percentage of germinable seeds per bag as a basis for ranking the efficiency of the different bags. Fifty-nine of the 88 plants (67 per cent) which bore one or more Kraft bags and at least one other kind for comparison, perpetuated themselves by producing one or more seedlings. Of this number, the Kraft bags produced the highest percentage of germinable seed per bag, in 39 cases (66 per cent). In 5 cases the Kraft bags ranked second, in 3 cases they ranked third and in 11 comparisons the seed from them failed to produce any plants, whereas one or more of the other kinds of bags contained seed which did produce one or more plants.

Of most interest, however, is the fact that in 19 of the 39 cases where the Kraft bags produced the largest percentage of germinable seed per bag, the Kraft bags were the only ones to produce germinable seed. In other words, the use of Kraft bags enabled 48 per cent of these plants to be perpetuated that were not perpetuated by seed development under the other materials. Thus it seems the Kraft bags had a distinct advantage over the other kinds in favoring the production of viable seeds under the conditions of this experiment.

In the comparison of the two sizes of glassine bags there were 66 plants on which one or the other or both produced seed. On 35 of these plants (53 per cent) the 8 by 14 inch bags produced a higher percentage of seed than the 5½ by 12 inch. In 6 cases it was the only type of bag that produced any seed but tests showed that none of the seed from these plants germinated.

The germination results showed that the seed from the 8 by 14 inch bags produced a greater percentage of germinable seeds in 55 per cent of the cases. There is apparently very little, if any, difference between the results from the 8 by 14 and 5½ by 12 inch glassine bags.

Parchment paper bags were used on 19 plants which produced seed. No seed was produced under the parchment bags on 13 (68 per cent) of the plants. When germinated only 3 (15 per cent) of the plants produced seedlings. This type was therefore inferior to the Kraft or glassine bags for use as isolation material for beets.

In conclusion it should be mentioned that some of the Kraft bags had started to disintegrate before they were removed from the plant in spite of the fact that the season during which they were exposed was not unusually rainy. All of the flowers within the bags had matured, however, in advance of the time disintegration was first noticed. It is conceivable that in a rainy or foggy season, disintegration resulting in holes might take place before the enclosed flowers had matured. No holes due to natural disintegration were found in the glassine or parchment paper bags.

The detail data also show that the average number of seedlings per "seed ball" is positively correlated with the percentage germination.

Summary

A comparison of the results obtained in 1932 at Arlington Farm, Virginia, from the use of 10-pound Tiger Kraft paper bags, 8 by 14 inch medium-weight glassine, 5½ by 12 inch medium-weight glassine bags and 4 by 11¼ inch parchment paper bags as isolation materials for the production of selfed table beet seed shows that as regards the percentage of seed set and percentage of germinable seed, the Tiger Kraft bags were superior to the other kinds, there was no significant difference between the two sizes of glassine bags, and the parchment paper bags were inferior to the other kinds used. The Tiger Kraft bags were more subject to early disintegration than the glassine or parchment paper. The average number of seedlings per "seed ball" is positively correlated with percentage of germination.

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Effects of the Fertilizer Treatment on the Growth, Yield and Quality of Henderson Bush Lima Beans at Successive Stages of Maturity*

By R. L. Carolus, *Virginia Truck Experiment Station, Norfolk, Va.*

SEED of the Henderson Bush lima bean supplied by the canner, was planted with a two row drill on July 1 and 2 and the crop harvested over a nine day period from September 5 to 14 during 1932.

Field Plot Technique

Fourteen fertilizer treatments were replicated twice in the area that consisted of 66 one-thirtieth acre plats arranged in three tiers of 22 plats. Every third plat was used as a check and fertilized with a 4–8–8 mixture at the rate of 400 pounds per acre. Treatment consisted of varying either NH_3 in 2 per cent gradients from 0 to 6 or the P_2O_5 in 4 per cent gradients from 0 to 16 or the K_2O in 4 per cent gradients from 0 to 16 in a basic treatment of a 4–8–8 mixture applied at the rate of 800 pounds per acre. Plats without fertilizer and others fertilized with the canner's own mixture were also included.

The nitrogen in the mixtures was derived as follows: Forty per cent from 10 per cent blood meal, 30 per cent from 20 per cent sodium nitrate, and 30 per cent from 25 per cent ammonium sulfate. Potassium chloride was used as the source of potassium, and the phosphorus was derived from superphosphate.

Each plat (104 x 14 feet) contained six rows spaced 28 inches apart. The two outer rows and a 12-foot border area on each end of the plats were not harvested for experimental records. The other four rows in each plat were subdivided into four 20-foot sections A, B, C, and D. This arrangement cut each plat into sixteen 20-foot row harvesting units. At the time of harvest 25 plants typical from the standpoint of growth and uniformity of spacing, considered as a unit, were pulled from section A of row one, section B of row two, section C of row three, and section D of row four of each plat. In any one day four 25 plant units were taken from each of the 22 plats of a tier. Three successive days were needed to complete the harvest on all three tiers. The same plats were utilized in a second and third harvest made during successive 3-day periods. Nine consecutive days, eliminating Sunday, were utilized in completing the three harvests from each tier.

This method showed the rate of development and furnished records of the yield from the small green stage, through the maximum yield period, to the semi-dry bean stage. By this plan any variation in the

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*The work herein reported for 1932, is one phase of a canning crop lima bean study, being conducted by this Experiment Station in cooperation with the Taylor & Caldwell Canning Company of Walkerton, Va.

rate of maturity due to fertilizer treatment, may be eliminated by selecting the optimum yield of each treatment for comparative purposes.

Analysis of Records

Records were taken on each 25-plant unit. The weight of vines including pods, of pods alone, and of each of the four grades of shelled seeds was recorded. The white seeds were separated from the green beans by hand and classified as grade No. 4. The green beans were graded on the basis of size. Seeds grading No. 1 passed through a screen containing holes $\frac{27}{64}$ of an inch in diameter; No. 2, through holes $\frac{30}{64}$ of an inch; and No. 3 consisted of larger green beans.

From the canner's point of view total yield is only one of the factors that determines the value per acre of a lima bean crop; another being the relative amount of each of the four grades that make up this total yield. An index of value was determined for each grade of beans, by subtracting the cost of the packing operations from the price offered by jobbers for each grade. Green No. 3 beans have a market value of 11 cents a kilogram for canning purposes. From the index of value it was calculated that on the basis of 11 cents a kilogram for No. 3 beans, No. 1 beans were worth 16.2, No. 2 beans, 12.9 and white beans 7.4 cents per kilogram. Using these figures the acre value for each grade for each 25-plant unit was determined. The average value per case was determined by dividing the yield in cases per acre into the acre value of the particular harvest. High average case values denote a proportionately larger yield of the smaller, more valuable grades than of the less valuable white beans.

Discussion

The adverse climatological influences under which the crop was produced in 1932, probably markedly influenced the results. During April, May, and June, a large deficiency in the rainfall brought the soil moisture to a very low level. Between planting and harvest only 4.8 inches of rainfall was recorded. This nearly semi-arid condition occurring on a well-drained soil markedly accentuated the effect on growth and yield of any slightly depressed area that had a relatively slightly higher organic matter content. This condition of soil dryness also limited the availability of the elements in the fertilizer mixture. The rapid acceleration in the rate of maturity accompanied by a small pod set and poor yield was also due to this unfavorable climatic condition.

In Table I the effect of the maturing processes on the factors of yield, value, quality, and plant weight are shown through the range of a continuous 9-day harvest period in 1932. These results for each day are means of eighty-eight 25-plant unit groups, arranged irrespective of fertilizer treatment. This averaging was permissible because, due to the two replications in the tiers, each fertilizer treat-

TABLE I—THE EFFECT OF THE MATURING PROCESS ON THE YIELD, QUALITY, VALUE, AND PLANT WEIGHT OF LIMA BEANS

Section of Field	Date of Harvest	Per cent of Each Grade				Yield per A. (Cases)	Value per A. (Dollars)	Value per Case* (Dollars)	Pod/Vine Ratio	Seed/Pod Ratio
		No. 1	No. 2	No. 3	White					
A	Sept. 5	39.4	31.6	22.0	7.0	63.87	90.00	1.41	.390	.327
B	Sept. 6	34.7	32.4	16.7	16.2	62.42	83.06	1.33	.390	.381
C	Sept. 7	31.3	32.5	14.0	22.2	60.40	75.80	1.25	.390	.389
Mean 1st harvest†		35.1	32.2	17.6	15.1	62.20	82.95	1.33	.390	.366
A	Sept. 8	27.5	36.4	19.5	16.6	73.80	94.59	1.28	.408	.388
B	Sept. 9	22.8	32.3	16 6	28.3	64.47	74.52	1.15	.390	.441
C	Sept. 10	20.0	31.6	19.9	28.5	64.75	73.52	1.13	.372	.459
Mean 2nd harvest		23.4	33.4	18.7	24.5	67.67	80.88	1.19	.390	.429
A	Sept. 12	16.2	27.3	18.3	38.2	77.54	80.20	1.02	.389	.496
B	Sept. 13	13.6	20.3	13.1	53.0	62.87	56.82	0.93	.358	.508
C	Sept. 14	9.8	18.4	17.5	54.3	64.84	55.28	0.85	.339	.524
Mean 3rd harvest		13.2	22.0	16.3	48.5	68.42	64.10	0.93	.362	.509
Mean all harvests		23.9	29.2	17.5	29.3	66.10	75.87	1.15	.381	.435

*Exclusive of packing operation costs.
†Arithmetical mean.

ment was included in each day's harvest. Only slight increases in yield were obtained during the harvest period, due to the fact that it was initiated at the time when the yield was rapidly approaching its maximum. The dry weather, shortening the period of maturity, eliminated the possibility of showing a definite trend in yield, from a small harvest at the start, through a period of maximum yield to a decreased production due to the drying of the beans at the end of the period. The elevation of tiers B and C was from 4 to 6 inches higher than that for tier A, thus providing a smaller moisture content for plant growth on these two tiers. The marked influence of this slight topographical variation, during a dry period, is shown by an increase in both yield and quality of the beans produced on tier A as compared to the yield and quality of the beans produced on the other two tiers.

The great relative abundance of No. 1 beans is due to dry weather, which prevented maximum development and resulted in decreasing the average size of all beans by at least one grade. Under normal growing conditions a fourth grade of green beans is recognized and the largest volume of green beans is found in the third grade, but in 1932 the largest volume of green beans graded No. 2. Many beans in 1932, during the maturing process, changed directly without further growth from grade No. 1 to white beans as indicated by the relative smaller amounts of the other two grades than would be found in a normal distribution. A uniform decrease in the percentage of No. 1 beans and a corresponding increase in the percentage of white beans in addition to field observations substantiate the above statement. There is very little change in the distribution of the other grades during the 9-day harvest period.

The means of the three harvests show only a slight increase in the yield per acre through a 9-day harvest period. The smallness of this increase is due to rapid whitening and drying of the beans, caused by the influence of the dry weather in accelerating the maturity without a normal increase in size.

A rapid decline in the acre value is shown by the means of the three harvest periods, and an especially rapid decline of from $80.88 to $64.10 is shown between the second and third harvests. This rapid decline in acre value is due to the diminishing case value as strikingly shown by a 40-cent decrease in the value per case between the first and third harvest periods. This emphasizes the importance of carefully selecting the proper stage of maturity if maximum financial returns are to be realized.

The Pod/Vine ratios showing no appreciable increases during the first 6 days of the harvest period, indicate a lack of further pod development. The decrease in the ratios during the last two harvest days show that the pods are drying at a more rapid rate than that of the rest of the plant. This drying is associated with an important increase in the percentage of white beans found. The Seed/Pod ratio increased with maturity due largely to an increase in the size of

TABLE II—THE EFFECT OF EACH INGREDIENT IN THE FERTILIZER MIXTURE ON THE YIELD, VALUE, AND QUALITY OF LIMA BEANS

Harvest	Yield per Acre (Cases)				Value per Acre (Dollars)				Value per Case* (Dollars)			
	1st	2nd	3rd	Av.	1st	2nd	3rd	Av.	1st	2nd	3rd	Av.
Fertilizer Content												
Nitrogen (NH_3) (Per cent)												
0	60.06	66.41	70.89	65.79	82.62	83.80	70.96	79.13	1.38	1.26	1.00	1.22
2	64.33	68.81	75.88	69.68	88.93	80.86	72.95	80.91	1.38	1.18	0.96	1.17
4	65.31	72.25	70.19	69.25	87.72	84.93	66.99	79.88	1.34	1.17	0.95	1.15
6	66.51	65.59	72.39	68.15	87.72	77.76	69.08	79.09	1.32	1.19	0.95	1.15
Phosphorus (P_2O_5) (Per cent)												
0	64.53	65.82	74.42	68.26	86.86	78.84	73.25	79.65	1.34	1.19	0.98	1.17
4	59.03	66.88	71.46	65.79	82.19	81.29	66.27	76.58	1.39	1.21	0.92	1.17
8	65.31	72.25	70.19	69.25	87.72	84.93	66.99	79.88	1.34	1.17	0.95	1.15
12	71.18	78.22	75.43	74.96	92.89	88.64	68.95	83.49	1.30	1.13	0.91	1.11
16	60.74	70.54	64.06	65.11	78.41	84.76	64.15	73.55	1.29	1.20	1.00	1.16
Potassium (K_2O) (Per cent)												
0	62.34	64.61	64.12	63.69	76.69	74.08	59.09	69.95	1.23	1.15	0.92	1.10
4	66.45	68.51	66.96	67.31	87.88	80.22	64.89	77.66	1.32	1.17	0.97	1.15
8	65.31	72.25	70.19	69.25	87.72	84.93	66.99	79.88	1.34	1.17	0.95	1.15
12	62.30	68 69	72.46	67.82	84.66	85.11	71.91	80.60	1.35	1.24	0.99	1.19
16	68.49	74.58	76.43	73.07	96.17	93.43	74.00	87.86	1.44	1.25	0.97	1.22
No fertilizer	56.09	64.27	64.28	61.55	67.99	65.50	49.24	60.91	1.21	1.19	0.78	1.06

*Exclusive of packing operation costs.

the beans during the first and second harvests, and to a relatively rapid drying of the pods during the third period.

In Table II are shown the effect on yield, quality, and crop value of varying amounts of NH_3, P_2O_5, and K_2O in a basic 4–8–8 fertilizer mixture. All figures are averages of three successive days' harvests. Excessive drought and high temperatures were probably limiting factors to plant growth, reduced the effectiveness of the various plant nutrient ratios, and were responsible for certain inconsistencies in the data presented.

The use of potassium in the mixture resulted in an increase in both yield and crop value for all three harvests. The best quality beans as indicated by a case value of $1.44 were produced during the first harvest period on plats treated with 16 per cent K_2O. A study of the results shown in Table II in the light of the data shown in Table I suggests the possibility that some of the importance of potassium in the production of beans of a high acre value is due to its action in delaying the rapid whitening of No. 1 seeds.

Chemical Changes in Carrots During Storage

By Hans Platenius, *Cornell University, Ithaca, N. Y.*

Abstract

CARROTS were stored in experimental cold storage rooms at 32, 35, 40, and 50 degrees F. Samples for chemical analysis were taken at monthly intervals. With the exception of the 32-degree lot, the percentage of water increased slightly during storage, especially at the higher temperatures. It was found that during storage sucrose is converted to reducing sugar at first, later the process is reversed, sucrose increases again while there is a drop in reducing sugar. The conversion from one form of sugar to another takes place more rapidly at the higher temperature.

Effects of Certain Environmental Conditions upon the Growth Habit of the Henderson Bush Lima Bean

By LEON HAVIS, *Ohio State University, Columbus, Ohio*

THE bush lima bean (*Phaseolus lunatus*) has been systematically described (3, 4), its cultural requirements studied (6), and genetic studies of the plan have been made (1,2), but a detailed report of the effects of certain environmental conditions upon the growth habit of this plant has not appeared. One of the most undesirable variations of the plant is the frequent elongation or twining of the main axis. In most cases, when twining occurs, the pods on the terminal raceme reach maturity much earlier than those on the remainder of the plant. The beans in these pods are more mature, white in color and necessitate a special operation in commercial canneries of removing them by hand in order to give a product of uniform green color. The Henderson bush lima bean was used in some experiments at Columbus in 1932 to determine if possible the type of plant produced under different environmental conditions. Some varieties have a tendency to twine more than others, hence some further studies relative to this problem are being made.

In studying effects of planting distances on the plant form, plots 10 feet by 9 feet were used. These were replicated four times. The plants were thinned to 4, 10, 16, and 22 inches apart in rows which were 28 inches apart; except in one test in which the plants were 4 inches apart with 14 inches between the rows. These different planting distances produced a very noticeable effect upon the plant habit. The greater height in the thicker plantings was due to more rapid internode elongation, little being due to increase in number of internodes. The thickly planted beans grew more rapidly in height, especially at first, than the more thinly planted ones. No twining of the main axis was found, however, in any of these plants regardless of planting distance. No difference could be seen in the date of anthesis nor in the maturity of the fruit on July 26th when the experiment ended.

Cheesecloth containers (40 meshes per inch) composed of two, three, and four layers of cheesecloth were used to shade three plots of 25 plants each. The first flower opened on the plants under two and also under three layers of cheesecloth only 1 day later than those on the plants exposed to full sunlight. In the case of the plot covered with four layers of cheesecloth the plants were 6 to 7 days later in flowering, but the first flower opened at the same position on the plant, which was in the axil of the uppermost leaf and at the base of the terminal raceme. No consistent differences were found in the number of internodes of the plants under different light intensities even though the main axis of the plants under the shades was much longer and showed a decided tendency to twine. The internodes were consistently longer under the shades from the beginning of the

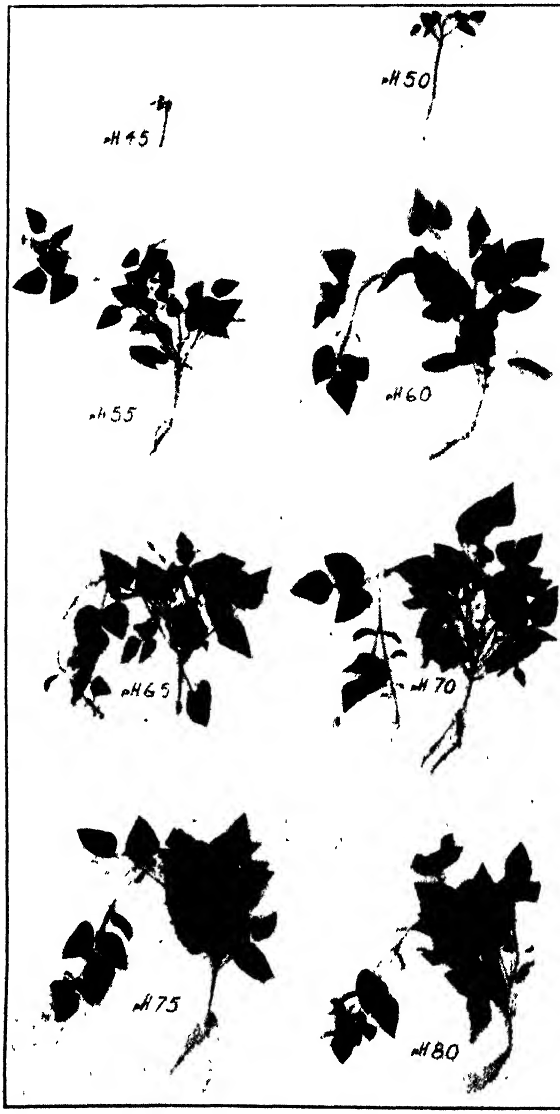

FIG. 1. Showing growth habit of Henderson bush lima bean plants in greenhouse at various pH values.

growth period, but true twining did not occur until the total number of nodes had been formed. Lengthening of the sixth and seventh internodes especially, then took place so rapidly that the plants showed very definite counter-clock-wise circumnutation. This period was reached 20 to 25 days after the seeds were planted. The racemes were much elongated under shaded conditions, lengthening of the peduncle taking place largely while the flower buds were developing. The time of flowering was prolonged to some extent by the denser shades.

In order to study the effect of the date of planting on the plant form, seeds were planted on May 14, June 3, June 17, and June 29. They were planted 12 inches apart in rows which were 36 inches apart and thinned to two plants per hill. In this way the plants were exposed to the same climatic conditions at different periods during their growth. The plants of the first three plantings showed the same general growth habits, none of the plants showing a tendency to twine. The plants of the June 29 planting were exposed to good growing conditions from the start and by July 21 all the nodes on the main axis were formed, though the upper two were only a few millimeters in length. July 21 and July 22 were cloudy and a light rain fell. During these 2 days, as well as during the following 2 or 3 days, the sixth and seventh internodes elongated rapidly, until on July 26 many of these plants showed a tendency to twine. The records showed that the plants in the previously studied plots were not exposed to cloudy weather and rainfall during this period in their growth. It is concluded from the above results, together with other field observations, that a reduction in light intensity, increase in soil moisture causing a more rapid growth, or both of these factors operating together will cause twining of the main axis and hence unequal development of pods if the plants are exposed to these conditions during a definite period in their growth.

The influence of soil reaction of this plant was studied in the greenhouses of the Experiment Station at Wooster. Eight plots of Wooster silt loam soil varying in pH from 4.5 to 8.0 were used. Aluminum sulfate and lime were used as necessary to maintain the various pH values desired. The roots of the plants in the most acid soils were brittle and there were very few lateral ones produced. Little difference could be seen in the root habit of the plants in soil above pH 6.0, all the roots being spreading and numerous. The plants developed most rapidly in the plots with a pH value of from 7.0 to 7.5, the fruits reaching maturity in these plots first. The length of time for the plants to reach maturity varied inversely with the pH values in the plots. The total length of the main axis increased as the soil became less acid (Fig. 1). The general habit is not comparable with plants grown under field conditions as all the plants in the greenhouse twined where they grew even moderately well, although always producing a determinate type of growth. It was observed that twining is common in these beans, when grown in the greenhouse, both in

winter and summer. The proportion of lateral branches to the general height of the main axis was about the same in all cases, the primary lateral branches reaching only about half the height of the main axis. The first flowers to open as well as the first fruits to mature were found on the base of the terminal raceme of the main axis or in the axil of the uppermost leaf.

Some of the results secured in the plots which were of low pH values were probably due to the toxicity of the aluminum salts which had been applied.

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Effect of Nitrogen, Phosphorus and Potash on Composition of Alaska Peas

By S. L. Jodidi and Victor R. Boswell, *U. S. Department of Agriculture, Washington, D. C.*

Abstract

PEAS were grown on untreated plots and on plots treated with readily available nitrogen, with superphosphate and with potash. There were no perceptible consistent differences in time of reaching harvest stage nor in distribution of sizes of peas. Contrary to a popular belief, fertilizing with potash did not decrease percentage of sugars or increase starch although it was accompanied by a slightly higher ash and ether extract content than the untreated or other treated plots. Potash treatment also was accompanied by a slightly higher proportion of protein to total nitrogen.

Fertilizing with nitrogen slightly increased percentage of sucrose, lowered starch content, and resulted in a lower proportion of protein to total nitrogen than peas from the check or any of the other plots, conditions characteristic of delayed maturity. Differences characteristic of hastened maturity produced by potash or the opposite produced by nitrogen are too small to be of any practical importance even when statistically significant. Phosphorus was without significant effect.

The Interrelation Between the Hydrogen-Ion Concentration of the Soil and the Growth Rate of Celery

By M. M. Parker, *Virginia Truck Experiment Station, Norfolk, Va.*

THE celery plant depends for desirable growth not only upon favorable climatic conditions, proper fertilization, and cultural practices but also upon the correct hydrogen-ion concentration of the soil. However, the soil reaction range for optimum growth of this plant fluctuates with such variable factors as soil type, organic matter present, forms of nitrogen applied, and weather.

Plants grown in soils of excessive acidity become dwarfed or die; the latter condition occurring especially during periods of adverse temperature and moisture. Lateral roots are produced near the surface of the soil after the lower roots die, but they fail to grow to any marked distance beyond the tap root. The entire root system is shortened, twisted, and distorted in appearance. The tips of the roots exhibit a brownish discoloration of their surface instead of the white of normal roots. Light green and brown areas develop among the darker green portions of the foliage which is stunted. In many cases the brown areas die causing a spotted effect.

The soil used was of organic origin and was classified as belonging to the Portsmouth series. It was treated with hydrated lime (72 per cent CaO) to bring it to the desired reaction and then placed in 15-inch terra cotta drain tile containers. The lime was used at the following rates to the acre: 1, 2, 3, 5, and 8 tons.

There were also check tiles to which lime was not added. The six treatments thus obtained were replicated five times. After the soil was placed in the tiles, well rotted stable manure was incorporated with the soil in only four of the series. The soil treatments were completed several weeks previous to planting. In addition a commercial fertilizer analyzing 7 per cent NH_3, 8 per cent P_2O_5, and 5 per cent K_2O was used in all the tiles at the rate of 2000 pounds to the acre. Sodium nitrate furnished the nitrogen, while superphosphate and muriate of potash, respectively, furnished the phosphoric acid and potash. Top dressing of similar materials was applied after the plants became established and later in the season nitrate of soda alone was used.

The Golden Plume variety was used and the young plants grown in the greenhouse were carefully selected for uniformity of growth at the time of transplanting to the test areas. All adhering soil was removed from the roots of the plants and three were then set in each of the tiles with the individual plants spaced about 8 inches apart.

The method of measuring consisted in drawing the foliage closely together in a clump and at weekly intervals until growth ceased recording its greatest height from the ground level.

Hydrogen-ion determinations of the soils were made with a quinhydrone set just prior to placing the plants in the tiles, about midway of the growing season and finally after the plants were harvested.

Effect of Soil Treatment on the Rate of Growth

There was a marked decrease in the height of the plants at the first measurement after transplanting to the tiles (Tables I and II). This drop in height was caused by the yellowing and subsequent shedding of many of the older leaves. The different rates of recovery from this check were very marked among the plants in the different soil reactions. The plants in the original soil (reaction pH 4.5) to which no lime had been added made little growth and in quite a few instances the plants died. This occurred toward the last of the growing season when hot dry weather prevailed. Both the roots and foliage exhibited the symptoms already described.

TABLE I—Height Readings of Celery Plants Grown in Soils of Different Reactions

Soil pH	Height at Trans.	May 8	May 16	May 22	May 30	June 5	June 12	June 19	June 26	July 7
	(Cms)	(Cms)	(Cms)	(Cms)	(Cms)	(Cms)	(Cms)	(Cms)	(Cms)	(Cms)
4.5	9	4.5	4.9	4.5	4.5	3.9	4.2	4.3	4.4	7.7
4.8	9	5.7	6.2	6.0	6.0	7.5	7.5	9.3	11.3	16.7
5.2	9	6.0	7.5	8.1	10.2	12.0	17.2	22.0	27.1	32.5
5.6	9	8.7	10.0	11.2	15.6	20.4	27.4	35.2	38.0	40.5
6.8	9	7.3	8.8	10.7	15.0	19.9	26.3	34.2	37.7	38.9
6.0	9	8.5	11.0	13.2	18.9	22.7	29.8	36.4	38.9	40.0

TABLE II—Height and Weight of Tops and Weight of Roots at Harvest

Soil pH	Height of Tops (Cms)	Weight of Tops (Gms)	Weight of Roots (Gms)
4.5	8±1.1	6± 2.1	5±1.5
4.8	17±2.2	34± 5.9	22±2.9
5.2	33±2.0	196±11.5	55±3.0
5.6	41±1.3	285±19.9	81±6.5
6.0	40±1.6	366±16.8	95±4.3
6.8	39±1.8	306±17.6	89±3.8

The soil brought to pH 4.8 produced plants which showed the same type of injury but their growth was only slightly better.

The addition of 4000 pounds of lime to the acre gave a soil of pH 5.2 which produced plants in type of growth intermediate between the poorest and the best lots. They never exhibited a vigorous growth of either roots or tops, and their size at harvest was considerably lower than that of the plants from the less acid soils.

The use of 6000 pounds of lime to the acre resulted in a soil of pH 5.6. At the time of the first measurement of the plants there was a slight depression in height, but at the time of the second measurement they had surpassed their original height at transplant-

ing. Thereafter growth was rapid but slightly less than that of the plants at pH 6.0.

It was found that in the soil under test the optimum reaction for the growth of celery was pH 6.0. This was secured by the use of 10,000 pounds of hydrated lime to the acre. This concentration produced no marked retardation in plant growth after transplanting and the growth rate was consistently uniform throughout the season. The plants at harvest were not superior to the plants grown at pH 5.6, but they maintained a rather constant advantage throughout the season.

The addition of 16,000 pounds of hydrated lime to the acre gave a soil reaction of pH 6.8. The plants did not show a much greater retardation of growth after transplanting than did those at pH 6.0, but they maintained a slightly lower growth rate. At harvest there was a significant difference in the height of the plants from pH 4.5 to pH 5.6 but there was no significant difference in the pH 5.6 to the pH 6.8 range. Similar results were secured from the yield by weight of the plant roots. The highest yield of tops by weight was obtained at pH 6.0 but not significantly greater than that produced at pH 6.8. The yield at each reaction interval below pH was significantly greater than that of the next lower reaction.

Summary

Celery plants grown in an organic soil with a reaction of pH 4.5 and pH 4.8 exhibited injury of roots and tops. At pH 5.2 there was a marked improvement in plant growth with less injury to the roots but the ultimate size of the plants was subnormal. A soil reaction of pH 6.0 was within the range for optimum growth in the type of soil used.

The Influence of Soil Type on Results from Paper-Mulch Trials with Tomatoes[1]

By E. N. McCubbin and K. C. Westover, *West Virginia University, Morgantown, W. Va.*

THE study here reviewed was in progress in 1930 and 1931 at the Lakin Experiment Farm in the lower Ohio Valley on a Wheeling fine sandy loam and at the Horticulture Farm at Morgantown on a Dekalb silty clay loam. These will be referred to hereafter as clay and sand soils. Both areas were well drained and of medium fertility. The sand was a typical "quick" soil, while the clay might be regarded as relatively "slow."

Each of the four plantings comprised at least 11 three-row plats. The number of tomato plants per row varied from 20 to 26 on the different plantings. Unstaked Bonny Best plants were used, the same spacings were employed, and the plantings at both locations were set at the same time each season. The odd-numbered plats of each planting were given the ordinary cultivation necessary to control weeds and to maintain a shallow soil mulch. They are here considered as check plats. The even-numbered three-row plats were covered completely with medium-weight mulch paper. Data were taken only on the middle row of each plat. The significance of the differences occurring between the mulched plats and the mean of the flanking check plats are determined by Student's method.*

Duplicate soil samples 7 inches in depth were taken at 2-week intervals on small unplanted areas similar in arrangement to the cropped plantings for the purpose of determining differences in soil moisture, soil acidity, and soluble soil nitrates.

1930 Study

Although crops at both places suffered from drouth in 1930 fair crop yields, considering the dry weather, were obtained. Of the total of 13.5 inches of rain which fell at Morgantown during the crop season less than half of this came after May 20th. At Lakin, 11.3 inches fell during the same period with about 4.5 inches after May 20th.

Table I shows that on the clay soil the mulch plats produced significantly greater yields of both marketable and cull fruits except for the early yield of No. 2 marketable fruits, where the difference was not significant. On the sand soil none of the yield differences was significant, with the exception of the total yield of marketable No.

*Love, H. H. A Modification of Student's Table for use in Interpreting Experimental Results. Jour. Amer. Soc. Agron. XVI: No. 1, 68–73. Also Love, H. H., and Brunson, A. M. Student's Method for Interpreting Paired Experiments. Jour. Amer. Soc. Agron. XVI: No. 1, 60–68.

[1]Published with the approval of the director, West Virginia Agricultural Experiment Station, as Scientific Paper No. 125.

TABLE I—COMPARISONS OF TOMATO YIELDS FROM MULCHED AND CLEAN CULTIVATED AREAS ON SAND AND CLAY SOILS, 1930.

Comparisons	Clay Soil—Morgantown				Sand Soil—Lakin			
	Mean Difference in		Odds	In Favor of	Mean Difference in		Odds	In Favor of
	Pounds per A.	Per cent			Pounds per A	Per cent		
Early Yields (First 24 Days (Morgantown) and 22 Days (Lakin) of Bearing)								
Marketable No. 1's	1,916	23.6	93	Mulch	142	28.6	5	Check
Marketable No. 2's	428	13.0	8	Mulch	4	1.7	1	Check
All Fruits Harvested	4,787	33.4	1,138	Mulch	17	1.3	1	Mulch
Fruits with Blossom-end and Soft Rots	2,435	82.9	3,332	Mulch				
Cracked Fruits					137	42.7	4	Mulch
Total Yields								
Marketable No. 1's	3,294	24.9	184	Mulch	500	8.0	7	Check
Marketable No. 2's	1,431	14.1	48	Mulch	1,616	39.9	458	Check
All Fruits Harvested	7,363	26.8	1,249	Mulch	1.907	11.7	40	Check
Fruits with Blossom-end and Soft Rots	2,573	61.5	2,499	Mulch				
Cracked Fruits					566	17.5	5	Mulch

TABLE II—COMPARISONS OF TOMATO YIELDS FROM MULCHED AND CLEAN CULTIVATED AREAS ON SAND AND CLAY SOILS, 1931.

Comparisons	Clay Soil—Morgantown				Sand Soil—Lakin			
	Mean Difference in		Odds	In Favor of	Mean Difference in		Odds	In favor of
	Pounds per A	Per cent			Pounds per A.	Per cent		
Early Yields (First 18 Days (Morgantown) and 16 Days (Lakin) of Bearing)								
Marketable No. 1's	1,290	42.7	70	Mulch	338	14.0	6	Check
Marketable No. 2's	183	28.7	19	Mulch	137	14.9	11	Check
All Fruits Harvested	4,668	75.1	2,499	Mulch	187	3.7	2	Check
Fruits with Blossom-end Rot	1,329	236.1	2,399	Mulch				
Fruits with Soft Rot	913	60.8	184	Mulch				
Cracked Fruits					90	83.3	1	Mulch
Total Yields								
Marketable No. 1's	607	3.1	2	Mulch	401	9.9	15	Check
Marketable No. 2's	1,981	28.0	112	Check	274	9.8	6	Mulch
All Fruits Harvested	2,382	7.4	17	Mulch	392	4.0	5	Mulch
Fruits with Blossom-end Rot	1,458	141.0	832	Mulch				
Fruits with Soft Rot	794	33.5	60	Mulch				
Cracked Fruits					205	19.8	4	Mulch
Total Set	2,880	7.8	47	Mulch	229	2.0	4	Check

2's and the total yield of all the fruits harvested. These significantly favored clean culture. The mulched plats also produced significantly more fruits with blossom end and soft rot on the heavy soil, and tended to produce more cracked fruits on the light soil than did those plats given clean culture.

1931 Study

In 1931, the rainfall was fairly evenly distributed over the crop season at both places except for a moderately dry period at Lakin from May 25 to July 13. The yields were above the average at both places.

The results of the 1931 trials, given in Table II, were very similar to those of 1930 with respect to the clay soil in that most of the yield differences were significantly in favor of the mulched plats. However, the total yield of No. 2 marketable fruits was significantly greater on the clean cultivated plats than on the mulched plats, in contrast to the results in 1930. The yield differences varied with treatment on the sand soil but in no case were these significant. Apparently the mulch had little influence on productivity. Again, we find significantly greater yields of diseased fruits from the mulched plats on the clay soil and, as before, a tendency for the mulched plats on the sand soil to yield more cracked fruits. In the latter instance the difference was of little or no significance.

Similar comparisons of the number of fruits in the different grades were made for 1931. All of these comparisons were directly in line with the yield results except one, the total number of marketable No. 1's on the heavier soil. In this case the number of fruits favored clean cultivation, while the yield favored mulch. Apparently the tomatoes from the mulched plats were heavier.

Actual measurements of the plants made both years showed that those on the mulched clay soil grew faster and remained larger throughout the season. There was little if any discernible difference in those grown on the sand soil.

The soil moisture content of the mulched clay soil was consistently higher both years, while on the sand soil there was no consistent trend in favor of either treatment. Apparently soil pH and soluble nitrate content were little influenced by mulch, for they varied without regard to treatment.

Discussion

Many of the experiments reported concerning the use of mulch paper on the various vegetable crops show it to increase the yield of tomatoes sufficiently to make its use practical. For the most part these trials have been conducted on medium sand and clay loam soil. The investigators, even though they secure increases in yield with other crops, generally suggest that careful consideration be given to all conditions of production before mulch is used. These studies strongly

indicate that the same degree of precaution may apply to its use with the tomato, if grown on light sandy loam soils.

Since there are no definite indications that the mulch influenced the pH of the soil and the amount of soluble nitrate on either soil type, these can be eliminated as direct causes of growth and yield differences.

Soil moisture content, which probably was partly responsible for the growth differences, was consistently higher on the mulched clay soil and seldom varied markedly above or below that of the check plats on the sand area. The difference in the effect of the mulch on soil moisture may possibly be accounted for by the fact that the sand soil is deep and the water-holding capacity considerably less than that of the clay soil. Also the seasonal difference in combination with the mulch treatment doubtless influenced yields and growth. The season at the Lakin station is normally 2 weeks earlier than at Morgantown and there the mulch treatments failed to produce the necessary difference in soil temperature in the early season to be reflected in growth as it did at Morgantown. Soil temperature determinations, taken at a depth of 6 inches, seem to bear this out. It is also entirely possible that the increase in soil temperature by mulch late in the season during the drouth period may have been injurious to the plants on the sand soil.

The increased amount of blossom-end rot during both seasons on the heavier soil may have been due to the high state of vigor of the plants during the early season when rainfall was less plentiful. The marked vigor of the mulched plants probably accounts for the significantly greater amount of imperfect fruit under this treatment.

On the sand soil the differences in soil moisture and temperature evidently had less influence on early growth. The amount of blossom-end rot at Lakin was so small from a comparative standpoint as to be considered negligible. The infection of the fruits by soft rots was doubtless of secondary nature.

These studies strongly indicate that the use of paper mulches on the tomato might be less profitable on the light soils than on the medium and heavier types.

The Effects of Storage Temperature and Humidity on the Keeping Quality of Onions

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THERE has been comparatively little research on the physiological effects of different storage conditions on onions. With a view to determining some of these effects on commercial varieties held under conditions likely to be met in commercial or farm storages, a series of experiments was conducted from 1925 to 1930.

Methods and Scope of Study

The varieties studied included Yellow Globe from the commercial muck lands of the Northeastern and Middle Western sections of the country; White Globe from the Middle West; Valencia from Colorado and from Walla Walla County, Washington; and Bermuda from Texas. Included also were onion sets of the Yellow Globe, Red Wethersfield, and Silverskin varieties. Practically all of the lots were purchased on the market. This report will deal only with the results obtained with Yellow Globe onions which are more or less illustrative of the results with all varieties.

The onions of the various lots were hand sorted to remove all decayed, injured, and misshapen specimens, and were then well mixed to insure a uniform sample. Sublots were stored in galvanized iron chambers approximately 3 feet, 6 inches in length, 2 feet, 11 inches in width, and 3 feet, 4 inches in height. Three each of the chambers were installed in storage rooms maintained at 32, 40 and 50 degrees F. Because of the free conductivity of the thin metal walls the temperature of each group of chambers followed closely that of the storage rooms in which they were placed. The desired humidities were regulated by exposing different quantities of calcium chloride or water in large shallow pans under the slatted false floor in each chamber. Air circulation was supplied in each group of chambers by means of small fans driven from a line shaft operated by a motor. In the door of each chamber was a small glass window through which wet and dry bulb thermometers could be read. The thermometers were located directly in line with the draft from the fans.

During the seasons of 1925–1926 and 1926–1927, low, medium, and high humidities in each group of chambers were arbitrarily maintained at approximately 65, 80, and 90 per cent. Subsequently it was decided to adjust the relative humidities in the respective groups of chambers so that there would exist a comparable evaporating efficiency in the corresponding low, medium and high humidities at all temperatures. Therefore, using the lowest humidity readily obtained at 32 degrees F as a basis, the others were fixed by calculation and maintained by the method of control already described. The relative

humidities with the comparable saturation or vapor pressure deficits are given in Table I.

TABLE I—RELATIVE HUMIDITY AND CORRESPONDING SATURATION DEFICIT MAINTAINED IN HUMIDITY CHAMBERS

Storage Temperature (Degrees F)	Low		Medium		High	
	Relative Humidity	Saturation Deficit (V P) in Mercury (Inches)	Relative Humidity	Saturation Deficit (V P) in Mercury (Inches)	Relative Humidity	Saturation Deficit (V P) in Mercury (Inches)
32	64.0	0.067	79.0	0.037	89.0	0.016
40	72.9	0.067	85.0	0.037	93.5	0.016
50	81.0	0.067	89.0	0.037	98.0	0.016

Detailed discussion of the respective lots of onions studied will be omitted except to state that the first season's work included two lots of onions from New York; one lot was well matured whereas the other was not. The second season, two lots from Michigan and one from New York were selected. The third season's work included some from New York and from Ohio, the fourth from New York and from Ohio, and the fifth one lot from Ohio. All the lots were put in storage about the last of November and inspections were made at approximately 30-day periods. At these inspections the dormant onions and those showing sprouting or top growth, rooting, and decay were counted. All specimens showing both sprouts and roots were classed as sprouted since among dealers sprouted onions are discounted more than rooted ones because they are usually soft and not usable, whereas rooted onions are usually firm and the roots rub off easily during handling. After each inspection only the sound dormant specimens were returned to the storage chambers.

RESULTS

The averaged accumulated results of the inspections made after approximately four months storage are shown in Tables II and III. Table II shows the results for the first two seasons with the same

TABLE II—AVERAGE CONDITION (EXPRESSED IN PER CENT) OF YELLOW GLOBE ONIONS AFTER APPROXIMATELY 4 MONTHS STORAGE AT 32, 40 AND 50 DEGREES F IN LOW (65 PER CENT), MEDIUM (80 PER CENT) AND HIGH (90 PER CENT) HUMIDITIES AT EACH STORAGE TEMPERATURE

Condition at Inspection	Storage Temperatures and Humidities								
	32 Degrees F			40 Degrees F			50 Degrees F		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Dormant...	79.8	73.9	41.9	58.3	46.8	36.2	64.7	49.0	16.3
Sprouted..	6.0	1.2	1.5	11.0	14.1	14.4	18.2	18.7	18.4
Rooted....	2.9	13.0	45.0	20.9	30.2	40.2	6.3	17.9	52.8
Decayed...	11.3	11.9	11.6	9.7	9.1	9.2	10.8	14.4	12.4

relative humidities maintained at each of the storage temperatures, and Table III includes those obtained under comparable saturation deficits.

TABLE III—AVERAGE CONDITION (EXPRESSED IN PER CENT) OF YELLOW GLOBE ONIONS AFTER APPROXIMATELY 4 MONTHS STORAGE AT 32, 40 and 50 DEGREES F IN LOW, MEDIUM AND HIGH HUMIDITIES (WITH COMPARABLE SATURATION DEFICITS OF .067, .037 AND .016 INCHES OF MERCURY

Condition at Inspection	Storage Temperatures and Humidities								
	32 Degrees F			40 Degrees F			50 Degrees F		
	Low	Medium	High	Low	Medium	High	Low	Medium	High
Dormant. .	96.1	91.2	86.8	80.9	79.6	55.6	63.3	63.3	28.2
Sprouted	0.5	3.0	1.7	4.1	7.0	11.2	23.2	21.0	22.9
Rooted. . .	0.0	0.5	5.3	9.2	5.9	24.5	3.8	5.9	37.0
Decayed . .	3.4	5.3	6.2	5.8	7.4	8.7	9.8	9.9	11.9

The relative values of the results in the two tables appear to differ in some respects as will be noted. Considering first the influence of storage temperatures and humidity on sprouting as found in the lots selected, Table II shows no apparent consistent difference resulting from differences in humidity. Temperature seems to have been the controlling factor. The least percentage of sprouting is shown at 32 degrees F in all humidities with an increase as the storage temperature increased from 32 to 50 degrees F. In Table III temperature again appears to have had the greatest influence on sprouting as in Table II but at both 32 and 40 degrees there is shown a slight tendency for the amount to increase with increase in humidity.

The amount of rooting that was found consistently increased with the humidity at all temperatures, with no apparent relation to temperature, during the first two seasons, as shown in Table II. In Table III this same general tendency is shown but it is not marked.

The results on decay in Table II show no influence resulting from either differences in temperature or humidity, while in Table III there is a very slight increase shown, correlated with the increase in humidity at each storage temperature. There is also shown a general but very slight increase in decay as the storage temperature increased.

All types of decay as found were identified, but by far the greatest amount was classed as Neck rot, caused by Botrytis.

SUMMARY

Sprouting of onions in storage at 32, 40 and 50 degrees F with low, medium, and high humidities at each temperature increased in amount as the temperature increased but with little response to differences in humidity, while rooting increased with humidity but with little relation to temperature. The amount of decay showed little response to either temperature or humidity.

The Effect of the Duration of Cutting Season on Asparagus that has been Flooded

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WITHIN the past few years, a considerable amount of interest has been shown in the proper length of cutting season for asparagus. Jones (2) from 6 years' data at Davis found that by extending the cutting season 2 weeks a slightly higher yield was obtained, but that the average size of the spears decreased. Haber (1) in Iowa found from 3 years' data that production increased in rows cut for different periods up to July 1 and decreased in rows cut later than this. In general, it is probably safe to state that there is a normal season of production which cannot be extended without deleterious effects. The normal cutting season of course would vary with the locality and somewhat with the season.

In the Sacramento-San Joaquin Delta, a number of the asparagus beds have become infested with the garden centipede (*Scutigerella immaculata*). It was found that by flooding the beds for a period of 3 to 4 weeks in mid-winter, the centipede could be somewhat controlled. Besides controlling this pest, flooding forced the asparagus from 10 days to 2 weeks earlier. Flooding to obtain early production has therefore become a general practice even when centipede infestation is not a problem, because of higher prices for the early asparagus.

As a rule these beds have been cut as long as the unflooded beds—that is, up to about July 1. After a bed has once been flooded, a decline in yield occurs in the following years. Certain growers think that flooding is harmful to the beds; but as the season is advanced 2 to 3 weeks by flooding, the longer cutting season might conceivably cause the decline in yield. If this theory is true, cutting should be terminated earlier than on unflooded beds.

In order to test this assumption, an experiment was started on December 3, 1930, in cooperation with the California Packing Corporation, to determine what effect the different lengths of cutting season would have on beds the year following a flooding. A 7-year-old bed of Mary Washington was selected and was divided into 24 plots of six rows each. Five different periods of cutting were made, each being replicated five times with the exception of the longest cutting period, which was replicated only four times. Each replication was arranged in the same order. A dam was made around the field, and water was pumped upon the land for a period of four weeks, although the land was actually inundated only about 18 days. The field was drained on January 2, 1931. Other treatments were of the ordinary commercial practices. During harvest the yields were kept daily. Because of the shape of the field, not all plots were of the same size; but none contained less than one-half acre. The yields for

the years 1931 and 1932 are given in Table I. In 1932, all plots were cut until June 15.

TABLE I—Production of Flooded Asparagus Beds

Plot	1931 Season		1932 Season		Plots Compared	Odds Odds
	Cut until	Yield (Pounds per A)	Cut Until	Yield (Pounds per A)		
A	April 20	2,182	June 15	6,384	B-A	40:1
B	May 1	3,236	June 15	6,825	B-C	53.9:1
C	June 1	4,937	June 15	5,937	C-D	14:1*
D	June 15	5,635	June 15	5,867	D-E	221:1
E	July 1	6,389	June 15	5,119		

*Not considered significant as calculated by Student's Method.

Table I shows a barely significant increase in Plot B over A, although B was cut 10 days longer in 1931. If this increase is really significant, no reason for it is known at present. In 1931, the quality of the asparagus fell off rapidly in plots cut after June 1. In 1932, the quality was also poorer on those plots cut longer than June 1, 1931. The data are not considered sufficient to determine the proper length of cutting after flooding; but as there is apparently no harmful effect in flooding, the deleterious effect must come from cutting too long after flooding.

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Incompatibility in Broccoli and the Production of Seed Under Cages

By O. H. PEARSON, *University of California, Davis, Calif.*

THE system of incompatibilities operating in cabbage has been described by Kakizaki (2) as being similar to that found and analyzed by East and his co-workers (1) in *Nicotiana alata* and *N. forgetiana*. The author has found a similar situation in broccoli, although the analysis is not yet completed. A breeding program for producing hybrid seed by crossing two pure lines of broccoli, each line intra-incompatible but the two lines inter-compatible, has recently been described (3). During the past season a preliminary test was made of a method for producing small quantities (about a pound) of hybrid seed for trial purposes, by the use of honey bees working on plants protected by cheesecloth cages from visitation by outside insects. The method was entirely successful and is described here, as being of possible interest to breeders of other plants.

The test was conducted at Chualar, California, about 10 miles southeast of Salinas, where large quantities of broccoli seed are grown. Two pairs of lines were planted in adjoining rows: one pair was composed of unrelated lines, each homozygous for different incompatibility factors, as shown by results of crosses made the previous year, and the other pair was made up of related lines homozygous for the same factor. The lines differing in factors should set seed, and this seed should be hybrid in nature; the lines having the same factor should be cross-incompatible and therefore should not set seed.

A cage was built around each pair of lines, just before the plants started to bloom. These cages were 15 to 20 feet long, 6 feet wide, and 4 feet high, and were covered with cheesecloth. All branches bearing open flowers were removed before the cages were covered. This fact explains the low seed yield of certain plants in group 2, only a small portion of the inflorescence of which remained unopened at the time of caging. In each cage was placed a box of Italian honey bees weighing about 1½ pounds and containing an old queen. These were supplied by Professor Eckert of the Division of Entomology and Parasitology, University of California. The box was about 6 by 6 by 9 inches in size, with a 1-pound section containing a small piece of foundation wax fastened to the top, and with wire screens to provide support for the bees. Egress was provided through a small hole that could be closed with a cork stopper. A hole in the top of the box large enough to admit the mouth of a milk bottle was covered with 16-mesh window screen. A pint milk bottle was filled with 50 per cent sucrose solution, and the mouth covered with washed tracing cloth. This bottle was inverted and placed on the screen so that the bees could feed on the solution, using it for energy in keeping

the hive warm and as a source of wax, until the plants came into bloom. To prevent the cloth from drawing away from the screen when pressure within the bottle was lowered during withdrawal of solution by the bees, a disc of wire screen was placed inside the bottles as a reinforcement for the tracing cloth.

As soon as the bees were placed in this small hive, they were fed with the solution. During the first week, while they were drawing out comb, and until the broccoli plants came into full bloom, each package of bees used about a pint of solution each day; near the end of the blooming period they used less than a pint a week. Aphis control was secured through the introduction into the cage of about a cupful of lady bird beetles; nicotine dust could not be used, since it is harmful to bees. During the 5 weeks that they were under the cages, each package of bees used about 4½ pounds of sugar. At the end of the blooming period one of the packages was dismantled, and in the comb were found about a hundred cells of brood. Obviously, then, the bees had been collecting pollen from the flowers, for brood can be raised only on a diet containing pollen.

One package of the bees that had been in a cage from April 13 until May 25 was loaned to a seed company who wished to test their efficiency in smaller cages, such as single plant isolations or small masses. Success, however, was very poor because of the weakened condition of the colony.

The seed yield from the two cages is shown in Table I. Evidently, there is considerable difference between the seed-setting ability of group 1 and group 2. Both in per cent set and average number of seeds per pod, group 2 compares very favorably with open-pollinated plants of similar breeding. Indications are, therefore, that the pollination of group 2 was practically as efficient as that of open-pollinated plants. Since the packages of bees were very similar, one can reasonably assume that pollination of group 1 was as thorough as that of group 2. Frequent inspections through the cheesecloth showed the bees working with equal industry in the two cages. Incompatibility, then, must explain the lower set of group 1.

Plant 4 of the 9–3–5–6–6 line in group 1 gave a high per cent set and a fair yield of seed. The average number of seeds per flower, however, is about the same as for its other sibs in this group. The better set on this plant cannot be explained, unless as the result of a physiological difference. Its sibs set much lower than it did, but considerably better than did plants of the 9–3–5–6–8 line. The same statement holds for the open-pollinated plants of the 9–3–5–6–8 line. Kakizaki suggests that minor factors may influence pollen tube growth, permitting some otherwise incompatible tubes to reach the ovules.

The results given here indicate that the use of small numbers of bees under cheesecloth cages is a possible method of producing small quantities of broccoli seed, if the compatibility situation is such that seed can be produced with the pollen available. Judging from the

observed action of bees in the cages described here, one should consider the following points when planning to use bees as controlled pollinating agents: (1) the relation of the number of bees to the size of the cage, (2) the maintenance of a supply of sugar solution, and (3) the use of the miniature hive over a reasonable period of time.

TABLE I—YIELD OF BROCCOLI SEED UNDER CAGES AT CHUALAR, CALIF., 1932

Pedigree	Total Flowers Opened	Total Ovaries Persistent	Ovaries with Seeds	Per cent Set	Total Number of Seeds	Average Number of Seeds per Pod	Weight of Seeds from Plant (Grams)
Group 1			Negative Cross S_1S_1 x S_1S_1				
9-3-5-6-8 pl. 1	128	111	4	3.6	4	1.0	—
9-3-5-6-8 pl. 2	135	119	2	1.7	2	1.0	—
9-3-5-6-8 pl. 3	161	135	0	0	0	0	.5
9-3-5-6-8 pl. 5	161	148	16	1.1	16	1.0	2.0
9-3-5-6-6 pl. 1	175	131	26	19.7	28	1.1	.5
9-3-5-6-6 pl. 2	131	109	33	30.3	90	2.7	4.0
9-3-5-6-6 pl. 3	157	139	41	29.5	62	1.5	6.0
9-3-5-6-6 pl. 4	120	107	80	74.7	120	1.5	12.0
Group 2			Positive Cross S_1S_1 x S_2S_2				
9-3-5-6-6 pl. 1	107	104	98	94.3	330	3.8	3.5
9-3-5-6-6 pl. 2	100	94	83	88.3	390	4.7	22.0
9-3-5-6-6 pl. 3	139	134	124	92.6	860	6.9	85.0
9-3-5-6-6 pl. 4	135	124	91	73.4	395	4.3	68.0
9-4-3-15-2-3 pl. 2	138	133	119	89.5	575	4.8	38.0
9-4-3-15-2-3 pl. 3	125	114	103	90.5	465	4.5	92.0
Group 3			Open Pollinated				
9-4-3-15-2-5-A	—	55	47	85.5	455	9.7	—
9-4-3-15-2-5-B	—	27	27	100.0	140	5.2	—
9-3-5-6-8-A	—	35	15	42.9	75	5.0	—
9-3-5-6-8-B	—	36	5	13.9	15	3.0	—
9-3-5-6-8-C	—	47	22	46.8	108	4.9	—
9a-13-1	—	78	72	92.5	510	7.1	—
9a-13-4	—	86	74	86.1	370	5.0	—
9a-13-5	—	36	33	91.8	294	8.9	—
9a-13-13	—	100	90	90.0	350	3.9	—
9-1-2-12-E	—	63	51	81.0	240	4.7	—

The length of time that the bees have been confined in the miniature hive is a factor which must be considered, because the number of bees available for pollination is the surplus over those required for hive duties. The queen bee cannot start laying eggs until the comb is well drawn out, a process which takes nearly a week. About 3 more weeks are required for maturation of the larvae, and after emergence several days or a week must elapse before the young bee can start flight. As the life of an adult honey bee is limited to about 6 weeks, and replacements cannot begin for at least 4 weeks, the strength of these small hives—that is, the number of bees available for field work—will be diminished by the death of the older bees. This difficulty can be overcome to a large extent by including a section of brood.

Such a miniature hive would have its period of usefulness considerably extended.

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The Effect of Potassium Deficiency Upon the Structure and Composition of the Sweet Potato

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ABSTRACT

YELLOW Jersey sweet potato plants were grown in sand culture with a complete nutrient solution for varying lengths of time and subsequently supplied with a nutrient solution lacking potassium but otherwise complete.

Associated with this minus potassium nutrient treatment the rate of nitrate assimilation decreased, the color of the leaves was light green, the rate of growth of the tops decreased, and the plants appeared similar to others grown with a limited nitrogen supply.

Analyses showed that the composition of the minus potassium plants was similar to that of low nitrogen plants, that the per cent of nitrogenous constituents was low and the per cent of carbohydrate constituents high compared with the respective constituents of sweet potato plants grown with complete nutrient solution. There was much less meristematic tissue present in the roots of the minus potassium plants. Therefore, with a deficiency of potassium in the nutrient medium, the sweet potato plant is much less able to assimilate nitrogen and therefore unable to produce in sufficient quantity those forms of assimilated nitrogen required for the formation of meristematic tissue which in turn is necessary for the rapid increase in diameter of the sweet potato root.

Progress Report on Breeding of Sweet Corn for Corn Borer Resistance[1]

By A. R. Marston and C. H. Mahoney, *Michigan State College, E. Lansing, Mich.*

THE European Corn Borer population is steadily increasing in Michigan. Practically five times as many eggs were deposited in 1932 as in 1931. Vigorous corn and favorable weather conditions were chiefly responsible for this egg deposition. However, immediately following the peak of the egg deposition, drought conditions prevailed and as a result larvae establishment was prevented. Nevertheless borer damage was common throughout the corn producing section of Michigan. Sweet corn growers found it difficult to market corn as practically all ears were infested by the corn borer.

TABLE I—Comparison of Number of Corn Borers to 100 Plants

Strains of Corn	1930	1931	1932
Pure Maize Amargo	2.0	7.4	5.7
Native corn (check)	19.0	44.7	53.8

Inbreds F_3, F_4, F_5, F_6 of native field corn crossed with Maize Amargo have shown fewer number of borers to 100 plants than inbreds of native corn x native corn when handled alike.

TABLE II—Comparison of Number of Borers to 100 Plants

Strains of Corn	1930		1931		1932	
	F_3	F_4	F_4	F_5	F_5	F_6
Inbreds Native Corn x Maize Amargo	6.0	3.0	14.4	12.2	9.4	8.3
Inbreds Native Corn x Native Corn	10.0	12.0	26.6	23.1	21.8	26.1

The Michigan Experiment Station is attempting through the process of plant breeding to develop strains of sweet corn resistant to the corn borer. Maize Amargo, a South American flint corn resistant to the attack of the corn borer, was crossed with commercial types of sweet corn. Uzal (1) has shown that Maize Amargo was resistant to the Grasshopper in South America and when first tested at Arlington, Massachusetts, was found to be resistant to the corn borer. Maize Amargo seed was furnished the Monroe Station in 1926 and has shown a high resistance to the corn borer in all tests conducted. Table I shows how it has compared to native corn in tests conducted at Monroe for the past 3 years.

Golden Bantam sweet corn was successfully crossed with Maize Amargo in 1927 and is now being tested in the F_4 generation. Early

[1]Journal Article No. 139 (M.S.) from the Michigan Agricultural Experiment Station.

Evergreen and Sunshine were crossed with Maize Amargo in 1929 and are now in the F_2 generation. The Inbreds of these crosses were planted each year in 10 hill plots with a commercial variety every fourth plot. Inbreds previously planted were selected and only the most resistant strains were used. The number of borers found and the percentage of infestation was used as a guide to determine their resistance. Corn borer counts were made under the supervision of Mr. C. B. Dibble of the Entomological Department of the College. All plants were dissected and count made of the number of borers present, number of points of injury by the borer ("works") and the percentage of plants infested.

TABLE III—COMPARISON OF THE NUMBER OF CORN BORERS TO 100 PLANTS AS A MEASURE OF RESISTANCE IN TESTS AT MONROE, MICHIGAN

Strains of Corn	Number of Borers to 100 Plants	
	1931	1932
Golden Bantam x Maize Amargo Inbreds F_3 (1931), F_4 (1932)	20.0	11.0
Pure Maize Amargo F_3 and F_4	7.4	5.7
Check (Duncan Field Corn)	44.7	53.8

Inbreds F_3, F_4 of Golden Bantam x Maize Amargo have shown considerable reduction in the number of borers to 100 plants as compared to the check.

TABLE IV—COMPARISON OF THE NUMBER OF WORKS, NUMBER OF INFESTED PLANTS AND NUMBER OF CORN BORERS IN 100 PLANTS AS MEASURES OF RESISTANCE IN TESTS AT MONROE, MICHIGAN, 1932

	No. Inf. Plants to 100 Plants	No. "Works" to 100 Plants	No. Borers to 100 Plants
Golden Bantam x Maize Amargo Inbreds F_4	10.9	21.7	11.0
Pure Maize Amargo Inbreds F_4 and F_5	8.3	12.9	5.7
Check (Duncan Field Corn)	44.7	102.4	53.8

All comparisons made in Tables, I, II and III have been according to the number of borers to 100 corn plants. This measure of resistance correlates rather closely with the number of works (points of injury) and number of plants infested in each 100 plants as shown in Table IV.

The popular method used in the past to compare data of this kind has been the "per cent of infested plants" and since these data are very closely correlated with number of borers per 100 plants and since it is much easier to compare progenies by the percentage method, this latter method will be used throughout the following discussion.

It has been shown (Table IV) that the average infestation of the pure Maize Amargo 1931 F_3 and F_4 inbreds was 7.4 per cent and for the 1932 F_4 and F_5 inbreds 8.3 per cent infestation. The 1932 Golden Bantam checks could not be used for comparison with plots as they were almost entirely destroyed by Stewarts Disease. The

Duncan field corn checks in 1931 showed approximately the same infestation as Golden Bantam. The Duncan checks in 1932 showed 44.7 per cent infestation so it might be assumed that Golden Bantam would have averaged at least this high had it not been for disease. Using these two limits the F_2 and subsequent data, based upon per cent of infested plants, have been divided arbitrarily into the following four resistant classes: Resistant (0–8 per cent infestation); Intermediate (9–19 per cent infestation); Low (20–40 per cent infestation); and Non-resistant (41 per cent and above).

The data in the preceding tables were based upon averages of all plots, but since the primary object of this work is to obtain pure strains of sweet corn resistant to corn borer, it might be well to study the pedigree of some of the individual families. The F_2 population of the cross Golden Bantam x Maize Amargo was not dissected for presence of corn borer, but if resistance is inherent in Maize Amargo, the F_2 population of Sunshine and Early Evergreen x Maize Amargo should show some resistant progenies. These progenies are shown in Table V.

TABLE V—PROGENY DISTRIBUTION OF RESISTANCE FOR SUNSHINE AND EARLY EVERGREEN CROSSED ON MAIZE AMARGO F_2

	0–8 Per cent Infestation	9–19 Per cent Infestation	20–40 Per cent Infestation	41 Per cent and Above Infestation
Resistance	High	Intermediate	Low	Non-resistant
Number of progenies	10	9	4	1

The F_2 data may offer a suggestion as to the mode of inheritance of corn borer resistance, but complete inheritance studies of corn borer resistance will be presented at a later date. Data are available, however, which prove that resistance to corn borer is a definite heritable character. There are many strains of the original cross of Golden Bantam x Maize Amargo which are as resistant to corn borer as pure Maize Amargo.

Seven Resistant F_3 families produced the following F_4 progenies: 6 Resistant; 3 Intermediate; and none of the Low or Non-resistant. Since most of the Non-resistant families were obviously discarded, their progeny tests cannot be presented.

Although homozygosity for this character has not been reached in the F_4 inbred generation, the progeny tests indicate that one or two more generations should produce sweet corn inbreds that show the resistance of pure F_6 inbred Maize Amargo. For example F_3 family 312182 with 6 per cent infestation in 1931 produced the following F_4 progenies in 1932: 8 progenies showing 0 per cent infestation, 1 progeny with 3 per cent, 1 progeny with 8 per cent, and 1 progeny with 10 per cent infestation. Apparently then one or two more generations of inbreeding and selection should make this strain more or less homozygous for resistance. There are several other families showing a similar high degree of homozygosity.

Sweet Corn Type and Resistance

It was observed among the F_3 families of Maize Amargo x Golden Bantam that very often the most highly resistant plots were the poorest sweet corn types. There were many of the inbred F_3 ears of some families that resembled their South American parent. In these same families there was segregation on the ear of sweet and flint seeds. Other families produced very few Amargo ears, but there were many ears still segregating on the ear for sweet and flint seeds. There were families also segregating for tassel ear, partial to almost entire self-sterility and other deleterious characters. Furthermore most of the F_3 families having the best sweet corn type were fairly low to intermediate in corn borer resistance. Rigid selection for type was made in the F_3 attempting of course to select from the most highly resistant families, but this was not always possible.

TABLE VI—1932 F_4 Inbred Progenies of Golden Bantam x Maize Amargo

Type	Good Sweet Corn Type			Poor Sweet Corn Type		
Per cent Borer Infestation	0 to 5	6 to 19	20 and Above	0 to 5	6 to 19	20 and Above
Number F_4 Progenies	21	12	2	21	6	3

It was suggested that resistance might be correlated with the Amargo type, or with late maturity. Marston and Dibble (2) have shown that resistance is not correlated with late maturity. Rigid selection was made on the F_4 progenies for type. All those progenies showing Amargo ears, or which were still segregating for sweet and flint seeds were classified as "poor type." The progenies showing a high percentage of sterility, tassel ears, or badly diseased ears were also classified as poor types. The F_4 progenies so classified are presented in Table 6.

After a study of Table VI it is quite apparent that there is no absolute correlation between Amargo ear type and corn borer resistance. There were 21 F_4 progenies of high resistance of both the good and poor sweet corn type. It is entirely possible that there may be linkage between factors for resistance and ear type, but that is beyond the scope of this piece of work, for the present at least.

Numerous inbred lines of Golden Bantam x Maize Amargo showing very high resistance have been obtained that are equal to, and several superior to, inbred lines of Golden Bantam. Many of these progenies have a higher sugar content than inbred Golden Bantam, but are from 8 to as high as 16 days later measured by their pollination dates.

A number of resistant inbred lines are fairly uniform for vegetative and ear characters and a number of single crosses have been made along with synthetic recombinations. As soon as the effectiveness of the inbred lines for pollenizers have been determined further synthetic

recombinations will be made. As yet none of the inbred lines have been tested for their value in top crossing with Golden Bantam.

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Relation of Temperature and Length of Day to Type of Growth in Celery, Cabbage and Beets

By H. C. Thompson, *Cornell University, Ithaca, N. Y.*

Abstract

THIS paper summarizes the results of studies carried on by the writer and by two of his graduate students during the past several years. The data show the effect of temperature and of length of day to type of growth—vegetative, or reproductive. Exposure of young celery plants to relatively low temperature (40 to 50 degrees F) for short periods, or growing them continuously for 50 to 60 days in a temperature range of 50 to 60 degrees F results in premature seeding when the plants are grown subsequently under normal field conditions, or in a medium-temperature (60 to 70 degrees F) greenhouse. Growing the plants continuously at 60 to 70 degrees F results in vegetative type growth. Cabbage and beet plants are influenced by temperature in much the same way as are celery plants. Cabbage and beet plants grown continuously for 3 years at medium and high temperatures remained in vegetative condition. In the case of the beet, the length of day also has an important effect on type of growth. By controlling the temperature under which celery and cabbage plants are grown, the type of growth can be changed at will; and by controlling both temperature and length of photoperiod, the type of growth of beet plants can be changed at will.

The results of these studies are given in detail in the following papers: (1) Thompson, H. C. Premature seeding of celery. Cornell University Agr. Exp. Sta. Bul. 480. 1929. (2) Miller, J. C. A study of some factors affecting seed-stalk development in cabbage. Cornell Univ. Agr. Exp. Sta. Bul. 488. 1929. (3) Chroboczek, Emil. Study of some ecological factors influencing seed-stalk devolpment in beets. (*Beta vulgaris* L.) Cornell Univ. Thesis. 1932. (To be published in full by the Cornell Univ. Agr. Exp. Station.)

Nodal Sequence of Flower Type in the Cucumber[1,2]

By T. M. CURRENCE, *University of Minnesota, St. Paul, Minn.*

IT is desirable to have a detailed knowledge of the flowering and fruiting habits of economic plants which have their growth modified by pruning and training. This is especially true of plants such as the cucumber which are used in intensive cultivation. The information to follow deals with the region of the plant on which the flowers form and the relative frequency of the two flower types in relation to season and growth of the plant.

The work of Tiedjens has demonstrated that the expression of sex in the cucumber plant is extremely variable and is the result of both environmental and genetical effects. Edmond has found the number of pistillate flowers to increase with decreasing length of day.

Perhaps the most interesting point brought out in this paper is the demonstration of how the sexual expression within an individual plant changes as the plant develops.

METHODS

Thirty plants of each of three varieties were grown. Each plant was allotted a space of 6 x 6 feet. The soil was of a sandy loam texture and had been in sod for several years. Manure and nitrate and phosphate fertilizers were applied previous to planting. The seed was planted June 12 and the data were taken September 1 to 10. The fruits were left on the vines until they developed to a marketable size.

The data were taken for each node, beginning at the first one to develop, and numbering them successively to the tip of the vine. The flowers at each node were counted and the number and sex recorded. These counts were made for the main stem and for the three longest laterals of each plant. A few of the hills failed to develop properly, making it impossible to include all of them in the records. As a whole, however, the plants were very vigorous and notably free from insects and diseases. The seed used was from ordinary commercial strains. The two forcing strains used were Davis Perfect and Arlington White Spine. The third variety, Cumberland Pickling, was recommended by the seed company as a very heavy fruiting strain. Most of the vines were less than thirty nodes in length and for this reason the data for nodes beyond this are thought to be of limited value.

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[1]Acknowledgment: Inasmuch as these data were collected when the writer was a member of the West Virginia Agricultural Experiment Station staff, he is indebted to the officials of that station for permission to use the material.

[2]Journal Series Paper No. 1166 of the Minnesota Agricultural Experiment Station.

RESULTS

Fig. 1 is a graphic presentation of the data on the percentages of the entire number on each successive node that were pistillate. The variety represented by the diagram is Davis Perfect. Diagrams for the other two varieties are omitted since they are not materially different from the one shown. The curves for both main stem and laterals are given, the solid line being for laterals and the broken one for the main stems. Upon the horizontal axis are plotted the node numbers from the base to the tip of the branches. The perpendicular axis represents the pistillate nodes in per cent of the total nodes for each successive number.

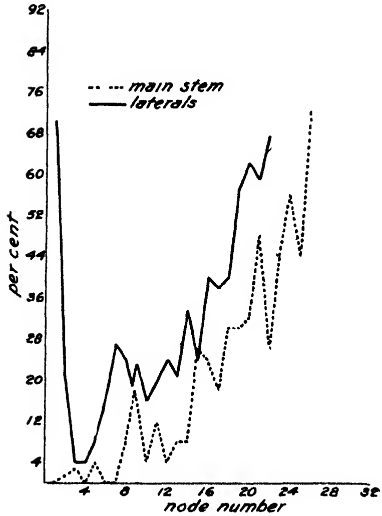

FIG. 1. Percentages of the successive nodes that were pistillate on the Davis Perfect plants.

The curves chiefly illustrate the increase of pistillate nodes as the vines lengthen. Some of the branches had only pistillate nodes after they attained a few nodes in length. Clearly there is a distinct change in the numerical relationship of pistillate and staminate nodes as the plants develop. The sex expression appears to undergo a gradual change from the strongly staminate to the strongly pistillate condition. The two types of nodes appear to be about equal in the region of the twentieth node. The laterals develop a greater number of pistillate nodes than do the main stems. This is in agreement with the changing from the staminate to the pistillate condition since the laterals are later in developing than are the main stems. It is also of interest to note the larger percentage of the first lateral nodes which were pistillate.

TABLE I—STAMINATE NODES TO ONE PISTILLATE NODE

Variety	Class Limits	Mean	Standard Deviation	Coefficient of Variability
Davis Perfect.	0.4 to 8.8	3.58±0.28	1.98±0.19	55.31±5.31
Arlington White Spine. . . .	0.8 to 6.4	2.80±0.21	1.36±0.15	48.92±4.12
Cumberland Pickling.	0.8 to 6.8	3.07±0.20	1.33±0.14	43.32±4.56

Under the conditions studied it may then be assumed that the plants underwent a change so far as fruit setting is concerned, showing a light set in the early stages and a gradually increasing one as the vines lengthen. However, if flowers are considered instead of nodes, a quite different figure is obtained.

A ratio was calculated in order to show the number of staminate flowers for each pistillate one. The staminate nodes always develop their flowers in clusters, while the pistillate are ordinarily borne singly. This situation results in an excess of staminate flowers. The actual figures resulting for the three varieties are Davis Perfect 24 staminate to one pistillate; Arlington White Spine, 21; and Cumberland Pickling, 18.

It is thought that some significance may be attached to the varietal differences found with regard to the number of staminate flowers per staminate node. The figures shown in Table II represent the data

TABLE II—STAMINATE FLOWERS PER STAMINATE NODE

Variety	Class Limits	Mean	Standard Deviation	Coefficient of Variability
Davis Perfect.	5.4 to 8.4	6.70±0.10	0.76±0.07	11.34±1.19
Arlington White Spine ..	5.0 to 7.9	6.37±0.13	0.88±0.09	13.81±1.52
Cumberland Pickling.....	5.4 to 8.2	7.00±0.12	0.78±0.08	11.14±1.07

obtained on this. The varietal differences are without statistical significance except for the comparison between Arlington White Spine and Cumberland Pickling. The means for these two varieties differ by 0.63 ± 0.177. Roughly, the difference is 3½ times its probable error. The coefficient of variability for the Arlington White Spine also is significantly greater than for either of the other varieties. There also appears to be a change with the growth of the plant in the number of staminate flowers that develop per node. For all of the varieties the first node averages about 8 to 10 flowers per node, while the later nodes give averages of five and six flowers per node. Therefore, the staminate expression seems to be reduced in flowers per node as well as in the number of staminate nodes.

In an effort to determine whether or not the flowering of the plant held any relation to other growth habits, the coefficient of correlation between length of vine expressed in number of nodes, and the average number of staminate flowers per staminate node was calculated. The length in nodes may be considered a rough measure of the vigor or growth of the vine. The coefficients of correlation were found to be as follows: Davis Perfect .30 ± .06, Arlington White Spine .15 ± .06, and Cumberland Pickling .59 ± .05. Therefore, the Cumberland Pickling shows a distinct positive correlation while the Davis Perfect shows a slight correlation. It is possible that this is either a species characteristic, since two of three varieties tend to show it, or that it is a varietal difference. However, with only the meager data here available it is unsafe to suggest more than possibilities.

An Hereditary Pithiness in Celery

By S. L. EMSWELLER, *University of California, Davis, Calif.*

THE occurrence of pithiness in celery has been a constant source of loss to celery growers. In California the writer has found pithy plants in all the commercial fields he has visited. They are found to some extent in all varieties, but it is the general belief among growers that it is most prevalent in the variety Golden Plume.

Field observations indicate that there are probably two types of pithiness in celery. In one type all the petioles of the plant are pithy and the plant is a total loss to the grower. The second type usually appears when the plant approaches maturity: only the outer petioles are pithy and these may be stripped off leaving a somewhat smaller but at least marketable plant.

Pithiness in celery has been attributed by growers to a variety of causes, such as high temperatures, lack of sufficient moisture, or a check in growth caused by drought or cold weather. Sandsten and White (3) and Austin and White (1) grew plants of the Golden Self Blanching variety from both French and American grown seed. In each case they counted the number of pithy plants and found that most of the French strains were free from pithiness, while the American strains generally produced a considerable number of pithy plants. In their work a plant was not counted as pithy unless all the petioles were pithy. When the three or four outer petioles were somewhat pithy and the heart solid, the plant was counted as non-pithy. They saved seed from two pithy plants and grew 12 plants from one and 20 from the other. In each case all the plants were pithy. Twelve plants were grown from seed harvested from a non-pithy plant and all 12 were non-pithy. From these results the authors concluded that, "pithiness in celery is due to the parent plant, and not to any extent to the soil, methods of culture, etc. The cause of pithiness is hereditary, and dates back to the seed producing plant."

Foster and Weber (2) in discussing pithiness of celery in Florida state, "The outer stems of the stalk become hollow, pithy, and soft. In many cases this trouble extends throughout the entire plant, rendering it worthless. The appearance of the disease may be associated with unfavorable growing conditions, such as frequent appearance of low temperatures which check growth and the resumption of favorable growing weather. In fact, any condition that checks the growth of the plant—such as, moisture, culture, setting, fertilizing, or adverse weather may cause pithiness."

At the present time most of the California growers believe that pithiness is caused by adverse environmental conditions. They generally recognize the two types of pithiness mentioned earlier in this paper. This investigation was undertaken for the purpose of determining accurately whether pithiness is hereditary and its mode of in-

heritance. In this paper we are dealing only with the type of pithiness in which the entire plant is affected.

PROCEDURE

In December, 1930, while making selections of desirable celery plants in a field of the variety Utah, a rather large number of plants was found in which all of the petioles were hollow. Six of these pithy plants were dug and moved to the breeding plot at Davis. Because of unfavorable conditions early in 1931 only two of these plants survived. They will hereafter be designated as plants 1 and 2. When they began to bloom each plant was covered with a heavy muslin cage. A very satisfactory yield of seed was harvested from each late in August.

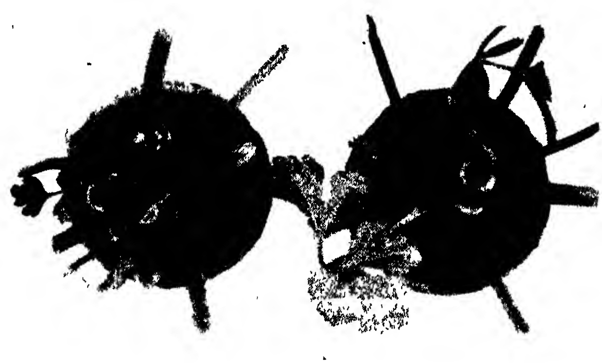

FIG. 1. Pithy plant at left, normal at right.

The first sowing of seed from the pithy plants was made on October 2, 1931. One hundred and two seedlings from plant 1 and 270 from plant 2 were grown in 3-inch pots. On February 11, 1932, half of each population was placed outdoors in unprotected coldframes. On March 15, 1932, all of these small plants were examined for pithiness. This was done by cutting through each plant about two inches above the soil in the pot. The cut at this point revealed the condition of all but the very youngest inner petioles. The small

TABLE I—SEGREGATIONS FOR PITHINESS IN SMALL CELERY PLANTS

Plant No.	Total Plants	Pithy Plants		Non-pithy Plants		Deviation	Dev./P.E.
		Observed	Calculated	Observed	Calculated		
1	102	79	76.5	23	25.5	+2.5	.84
2	270	208	202.5	62	67.5	+5.5	1.14
Total...	372	287	279.0	85	93.0	+8.0	1.42

plants could readily be placed into either a pithy or non-pithy class (Fig. 1). Table I shows the results of this examination.

The data inTable I clearly indicate that pithiness of the type studied is due to a single dominant gene. Fortunately the plants in our experiment were heterozygous, thus making a genetic analysis possible at once without the necessity of producing hybrids with our non-pithy lines. This condition occurred in the same proportions in both the plants grown in the greenhouse and outdoors in the coldframe. At the time the plants were cut, those grown continuously in the greenhouse averaged twice as tall as those grown in the coldframe. From this it is evident that checking growth by exposure to low temperatures has no effect on the expression of the gene.

TABLE II—NON-PITHY CELERY LINES (SMALL PLANTS

Line No.	Total Plants	Pithy
1–51	465	0
1–2–1	208	0
1–2–2	137	0
1–12–2	305	0
1–47–5	168	0
Total	1,283	0

On the same day that the seed from the pithy plants was sown, plantings were made of five inbred lines, all of which had descended from non-pithy plants. Four of these lines had been inbred two generations and the fifth but one generation. These five lines were handled in exactly the same way as the pithy lines. The plants in the inbred lines failed to show a single pithy specimen.

In order to see whether any of the solid petiole plants in the pithy lines would become pithy if grown on to maturity all the populations from plant 1 and 2 were set into the field on March 19, 1932. About two-thirds of the plants that were grown for some time in the coldframe developed seed stalks. The remaining plants were examined several times during the growing season and a final examination made on November 22. At this time none of the plants that had solid petioles when small had developed pithiness. All those plants that had been pithy when small were still definitely pithy.

The plants in the non-pithy lines were also transplanted to the field on March 19. On November 22, not a pithy plant was found in any of these lines.

On February 25, a second planting of seed from plant 1 was made in the greenhouse. The seedlings were transplanted to the coldframe on April 6, and to the field on May 28. The inbred lines that had shown no pithiness were also planted at this later date and handled the same as the progeny from plant 1. All the plants were spaced 8 inches in rows 3 feet apart.

All of the progeny from plant 1 were examined every few weeks during the growing season and pithy specimens located by cutting one

or more of the inner petioles. The entire population was harvested on December 8, and each plant carefully examined by cutting through a number of the outer and inner petioles. Those plants which showed a uniformly pithy condition of all petioles were classed as pithy. The plants that had solid stems did not have a single petiole that could have been called hollow. In a few plants of this type, however, there was some indication of a breakdown in the parenchyma tissue in a few of the outer petioles. Not a pithy plant was found in a total of 1509 in the inbred non-pithy lines. The segregation of pithy and non-pithy plants occurring in the population grown from plant 1 is shown in Table III.

TABLE III—SEGREGATIONS FOR PITHINESS IN MATURE CELERY PLANTS (PLANT 1)

Plant No.	Total Plants	Pithy Plants		Non-pithy Plants		Deviation	Dev./P.E.
		Observed	Calculated	Observed	Calculated		
1	300	226	225	74	75	+1.0	.19

MORPHOLOGICAL STUDIES

A microscopic study of the petioles of both pithy and non-pithy plants was made in order to determine differences in structure. Sayre

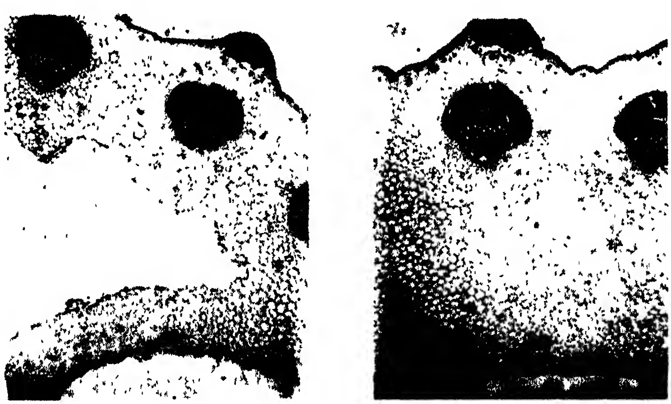

FIG. 2. Microphotographs of pithy petiole (left), normal (right).

(4) in studying the quality of celery as related to petiole structure, made a microscopic study of several pithy specimens and the examination seemed to show a direct correlation between pithiness and collapse of parenchyma cells. Two microphotographs of pithy plants indicated that the collapsed parenchyma cells were scattered throughout the petiole. A microphotograph of a petiole from a pithy and non-pithy plant in our population is shown in Fig. 2. It will be noted that in the pithy petioles the breakdown in the parenchyma is

in the center of the petiole. This was true in every pithy petiole examined. In all the non-pithy plants the parenchyma tissue showed no indication of disintegration. The ratio between the open area to the total cross section area of the petiole varied to some extent within the plant, and considerably from plant to plant. This variation between plants is possibly due to the fact that two-thirds of this class is heterozygous for the gene involved. No attempt was made to determine accurately the difference between plants homozygous and heterozygous for the character.

Discussion and Summary

The evidence presented indicates that the type of pithiness studied in this paper is dependent on a single dominant gene. In the early paper by Austin and White (1) the number of plants grown from seed produced on the two pithy plants was very small and no mention was made as to whether the two plants were self-pollinated or open-pollinated. It is probable, however, that each plant was homozygous for this gene.

It is very easy to understand why there has been variance of opinion as to the cause of pithy celery. While our study of the other type of pithiness is just begining there is no doubt in the mind of the author that we are justfied in speaking of two distinct types. It is a well known fact in California that after celery has been banked with soil some varieties will soon show pithiness of the outer petioles while other varieties can remain in the soil for a much longer period before any plants become pithy. The type of pithiness discussed in this paper, however, is present from the very young plant stage, and each new petiole as it appears is pithy.

In general while the plants were small it was impossible to distinguish the pithy from the non-pithy unless a careful examination was made. It is very likely that a few plants of this type are probably set into most celery seed fields. Since the condition is dominant, and there is undoubtedly considerable cross-pollination in celery, these few plants would cause some contamination of the seed. The varying amounts of pithiness found by Austin and White (1) in different strains can probably be accounted for in this way. As the plants become larger the pithy ones are easily identified by exerting pressure on the petioles which will readily collapse. There were no appreciable external differences, however, that distinguished these plants from the solid petiole type.

Since the solid petiole condition is recessive, it is a simple matter to establish strains of this type. The greatest care should be exercised at all times to exclude all hollow petiole plants from the seed field. By careful rogueing we should eliminate this type of pithiness rapidly.

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Inbreeding Studies with *Cucumis Melo*

By G. W. SCOTT, *University of California, Davis, Calif.*

ABSTRACT

The complete data will be published as a number of the Hilgardia series.

FROM a study of the effect of inbreeding four varieties of *Cucumis melo*, the following conclusions seem warranted: (1) A loss of vigor, as measured by the number and weight of fruits, does not necessarily result from inbreeding the Salmon Tint, Hales Best, Honey Dew, and Casaba varieties of muskmelons four to seven generations. (2) Inbred lines with fruit weights greater than, equal to, or less than that of the parent lines have been isolated in the Salmon Tint and Hales Best varieties. These differences are statistically significant. (3) Lines uniform for flattened or oblate fruits and for oblong or oval fruits, differing significantly from the fruit shape of the parent variety, may be isolated by inbreeding. (4) F_1's between inbred lines differing in fruit weight are intermediate between the two parents and exhibit no marked hybrid vigor. (5) The fruit shape of the F_1's of lines with flattened and oval fruits, respectively, is intermediate between that of the parents, indicating that this character is dependent on at least several factors. (6) The results of this study agree with conclusions of other investigators on the effects of inbreeding in the family Cucurbitaceae.

A Laboratory Exercise in the Statistical Study of Strains of Cabbage

By PAUL WORK, *Cornell University, Ithaca, N. Y.*

THIS paper reports an experiment in teaching. It is predicated upon the assumption that our students should understand a little of the meaning of measurement observations, and of the critique of data as exemplified in the methods of probable error. This need prevails not only for those who are to engage in research, but also for all those who may have occasion to read reports of scientific work. If college training for agriculture means anything, it means ability to evaluate research results as they appear. It is needless to point out to this group that no small share of published results are open to question, including some that are marked all over with the P. E. stamp. Such matters are usually debatable but every student who graduates from our colleges should be able to form an intelligent opinion of his own.

The experiment gains added significance since measurement observations and statistical treatment of data are so rapidly replacing verbal notes in present-day studies of types and varieties.

The experiment here reported represents a laboratory exercise in a course at Cornell University in Types and Varieties of Vegetables (Systematic Vegetable Crops). Its principal object was to learn whether in a limited time a group of average students, mostly undergraduates, could take measurements on variety characters, work out the probable errors, graph the results and have some idea of what they are doing.

The secondary object was to acquaint the students with the wide range of variation which prevails among strains of cabbage, and to familiarize them with a method of making size and shape diagrams based upon averages of many measurements.

The method used was developed by Dr. C. H. Myers and his associates in connection with his inheritance studies of cabbage and is recorded in an unpublished thesis by Juan P. Torres in the library of Cornell University. This paper also includes a classification of shapes based upon the relationships existing among the four measurements.

The exercise was preceded by an explanation of the value of measurements as compared with verbal notes, and of the probable error concept. One is sometimes astonished at the number of people, including some professional workers, to whom probable error means only a formula or nothing at all.

For this exercise Professor F. O. Underwood allowed the use of his strain test plots where some 23 stocks of Danish Ballhead cabbage were growing. The students worked in groups. Using about 20 heads of each trial sample, they recorded weight, vertical diam-

eter, and three horizontal measurements at points dividing the vertical axis into four equal parts, embodying the essential features of the Myers-Torres method. (See Fig. 1). These data were recorded on tabular sheets and probable errors were calculated for one or two strains by each student, using Peters' formula. Attention was called to the applicability of the Bessels and the Peters type of calculation as compared with the Student and Fisher methods. Each student plotted a graph showing the shape of head represented by his set of averages and handed it in with his figures. The average measurements of all the students were then assembled, mimeographed, and returned to them along with a blue print assembly of the 23 diagrams for study and report. There was then opportunity to discuss the differences in size and shape of heads and whether or not they might be significant Fig. 1 and Table I show representative graphs and typical data.

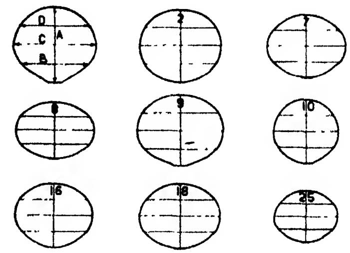

FIG. 1. Graphs based on measurements of cabbages.

TABLE I—AVERAGES OF MEASUREMENTS OF STRAINS SHOWN IN FIG. 1, WITH PROBABLE ERRORS

Strain Number	Measurement (Ins.)				Weight (Ounces)
	A	B	C	D	
2..........	5.7±.06	5.9±.11	6.5±.10	5.8±.09	57±1.7
7..........	5.0±.11	5.2±.09	6.3±.11	5.3±.12	51±2.4
8..........	4.3±.11	5.3±.13	6.1±.15	5.4±.13	42±2.9
9..........	5.5±.10	5.9±.16	6.8±.17	6.2±.15	61±3.4
10..........	5.0±.09	4.5±.09	5.2±.11	4.5±.09	38±1.7
16..........	4.9±.13	5.2±.11	6.1±.15	5.4±.13	51±3.1
18..........	5.0±.05	5.7±.07	6.3±.09	5.5±.09	47±1.7
25..........	4.0±.05	4.5±.09	5.0±.08	4.3±.07	24±1.0

The data not only show a wide range in size and shape of heads, but also in uniformity. Dr. Myers' "A" strain, while small in size, shows probable errors narrower than those of any other stock in the test. Others also show a wide range in variability.

In conducting a laboratory exercise of this sort, students must be warned that a single season's results are not sufficient, that there should be replications and also that measurements taken by a group of inexperienced workers cannot be as well standardized as would be the case in actual research.

That this experiment was successful was attested by the marked interest of the students in the exercise, by the uniformity of their

results, by their answers to questions, and by their own questions on method and calculation. Incidentally, the undergraduates did almost as well as the graduates. It is not claimed that every one of these students is ready to use the method for himself, or to capably evaluate statistical results, but it seemed that the group materially increased their appreciation of the methods used in modern research. Most of us who teach have been inclined to undervalue the capacity of our students to receive and assimilate concepts and methods which we often leave for graduate study.

While this study was only a laboratory exercise, some of the results are most suggestive. The importance of strain and stock differences within varieties is emphasized.

The probable errors show that in the comparison of some stocks a difference of about .2 inches in the dimensions considered becomes significant. In other cases a difference of .8 inches is necessary to be significant.

Probable errors for weight are considerably wider than for measurement.

From the practical standpoint of assistance to commercial producers, we are directed toward the conduct of careful statistical studies of strain and stock differences, throwing light upon performance characters as distinguished from our ordinary variety trials which reveal chiefly the grosser characters that distinguish varieties.

The Amount of Blossom and Pod Drop on Six Varieties of Garden Beans

By A. M. BINKLEY,[1] *Colorado Agricultural College, Fort Collins, Colo.*

DURING the 1931 growing season, reduced yields of beans were reported which apparently were due to blossoms and pods dropping off the plants. The season was unusually dry and hot, with some shortage of irrigation water in several of the canning factory districts. Observations made that year during the blossoming and picking periods indicated a possible association of such factors as high air temperatures, sudden fluctuation in air temperatures from high to low points, and uneven soil moisture supply, with blossom and pod drop. Twenty-five varieties were under study on the station, and enough variation occurred between them to indicate a varietal difference.

In 1932, 6 of the 25 varieties were planted to further study the amount of blossom and pod drop to associate such loss with yield, earliness and pod measurements.

MATERIALS AND METHODS

The selection of the six varieties for detail studies was made on the basis of relative amounts of bloom in 1931; three appeared to be heavy bloomers and three light.

Daily counts of the number of blossoms that appeared on each plant were taken, and each blossom marked as it opened with a very small drop of waterproof color. A master tag was attached to each plant, on which the daily count was recorded. The daily count was likewise recorded in a field record book. The color marking was placed on the base of the flower in such a manner as not to injure or disturb the blossom. Records were then taken on each individual plant of the number of pods that reached marketable size. Records were also taken on about 45 individual plants for each variety, and a total blossom count of over 16,000 was made in the study. By subtracting the total number of pods picked from each plant from the total number of blossoms that opened, the amount of blossom and pod drop was determined. Students' method of paired plots was used to calculate the difference between the total number of blossoms opened and pods picked. The significance of the difference was determined by Fisher's "t" test. The results are tabulated in Table II.

[1]The author wishes to express his appreciation to Dr. E. P. Sandsten for the opportunity to work on the problem, and the facilities made available for the work.

Experimental Results

The variation in the amount of drop is quite wide with individual plants within a variety. The results of a count on Burpee's Saddleback Wax variety are given in tabulated form to show the variation. The data on the other five varieties are included in the summary table only. The loss, or per cent of the blossoms and pods that dropped, varied between 44.25 per cent and 76.21 per cent, as will be noted in the summary table.

TABLE I—The Amount of Blossom and Pod Drop on the Saddleback Wax Variety of Garden Beans

Plant Number	Total Number Blossoms per Plant	Total Number Pods Picked per Plant	Plant Number	Total Number Blossoms per Plant	Total Number Pods Picked per Plant
1	49	19	24	34	14
2	41	21	25	42	22
3	45	22	26	39	26
4	38	20	27	34	25
5	25	14	28	52	24
6	46	29	29	22	10
7	50	26	30	34	23
8	46	30	31	34	21
9	26	24	32	42	17
10	48	29	33	43	21
11	31	14	34	54	24
12	28	20	35	57	41
13	55	26	36	46	23
14	58	26	37	47	24
15	45	28	38	43	26
16	36	17	39	56	26
17	45	17	40	44	33
18	30	21	41	27	15
19	22	19	42	32	19
20	45	26	43	62	36
21	48	27	44	32	20
22	32	18	45	30	19
23	51	27			
Total				1,846	1,029
Av. per Plant				40.09	22.86
"t" Value				16.50	——
.01 Point				2.57582	——

Table I gives the total number of blossoms that opened on each plant for this variety, and the total number of pods picked; the average per plant, and the "t" value are given at the bottom of the table.

The results on this variety show that there was an average of 40.09 blossoms opened per plant and that there were only 22.86 pods per plant actually picked. The "t" value was 16.5, and the .01 point was 2.57582. The odds that the difference is significant are many times more than 100 to 1.

The summary table shows the results on all varieties studied.

TABLE II—SUMMARY OF BLOSSOM AND POD STUDIES ON SIX VARIETIES OF GARDEN BEANS

Variety	Saddle-back Wax	Violet Flagolet Wax	Red Valentine	Currie's Rust-proof	Keeney's Kidney Wax	Canadian Wonder
Number Blossoms	1,846	2,676	2,375	2,384	3,005	4,032
Number Pods Picked	1,029	852	1,052	914	954	959
Number Plants	45	50	46	45	45	44
"t" value*	16.5	18.28	15.43	12.81	16.5	16.09
Per cent Drop Blossoms and Pods	44.25	60.68	56.12	61.66	68.27	76.21
Average Yield per Plant (Oz.)	3.12	3.10	2.76	2.59	1.68	1.54
Average Days to First Pick	63	62	66	62	67	71
Average Pod Length (Cm)	10.52	15.11	9.35	11.89	12.93	13.49
Average Pod Width (Cm)	1.10	1.40	1.04	1.26	1.06	1.31
Average Pod Thickness (Cm)	1.08	1.05	1.12	.91	.95	.81

*The .01 point amounted to 2.57582 on each variety studied.

The results of the "t" test for significance of the difference show that with each variety the odds are greater than 100 to 1 that the difference is significant. The large number of blossoms opened on plants within a variety does not mean that the pod set and yield will be heavy. In determining the degree of association between total number of blossoms and yield per plant, the correlation coefficient was $r = —.8895$, which is a high negative correlation. There was also a high negative correlation between the yield per plant and the per cent blossom and pod drop on the six varieties studied. In considering these two factors the correlation coefficient was $r = —.7785$. Apparently, there are considerable inherent differences in varieties and their physiological resistance to conditions causing drop losses.

During 1931, an attempt was made to correlate weather conditions such as air temperatures, rainfall, and wind with the amount of blossom and pod drop.

The effect of irrigation on drop losses was also studied. The preliminary work seems to indicate a relationship to those factors, since there was some increase in drop losses following several days of extremely high air temperatures, and fluctuating air temperatures from high to low. Where the soil was too dry during the blossoming and picking period and then irrigated, the amount of drop increased 20 to 30 per cent. This indicates the possibility that less drop would result from maintaining as uniform a soil moisture supply as possible during the blooming and picking period.

More work is necessary to definitely associate the above mentioned factors, however, the preliminary data indicate the possible relationship. The blooming and picking season seems to be a critical period when the bean plant is especially sensitive to varia-

tion in environmental conditions. The bean plant apparently produces many more blossoms than the plant could support if all the flowers were fertilized and pod development completed.

Conclusions

The results of the investigations to date show that (1) there is a significant difference between the number of blossoms produced on individual plants within a variety and the number of pods actually picked; the odds are greater than 100 to 1 that the difference is significant on all varieties. (2) There is a wide range of variation in the number of blossoms produced and the number of pods picked on individual plants within a variety. (3) On the six varieties studied, a high negative correlation was found between the total number of blossoms per plant and the yield per plant. There was also a negative correlation between the per cent blossom and pod drop and yield per plant. (4) The per cent of blossom and pod drop on the different varieties varied between 44.25 per cent and 76.21 per cent. (5) The blossoming and setting period appears to be a critical period when the bean plant is especially sensitive tc wide variations in environmental conditions of growth.

Fermenting Cornstalks as a Substitute for Manure in Hotbeds

By E. M. EMMERT,[1] *University of Kentucky, Lexington, Ky.*

HORSE manure has long been used as a source of heat for hotbeds. It is quick in action and the spent manure can be used as a fertilizer. However, the use of manure has the following disadvantages: (1) It is likely to become too hot; (2) much heat is lost in letting the bed cool before planting; (3) ammonia fumes from manure may be injurious to plants; (4) the heat lasts only 2 to 3 weeks; (5) often the young plants are spindly and succulent from excessive bottom heat while small, and (6) manure is becoming expensive and hard to get.

Because of these disadvantages, cornstalks were tried at the Kentucky Experiment Station as a substitute for manure. When cornstalks were shredded or cut to about 1-inch lengths, packed into a hotbed and made thoroughly wet, it was found that a temperature of about 100 degrees F was reached in 2 or 3 days, and a range of 80 to 120 degrees was maintained for about 1 month. The addition of cotton-seed meal caused somewhat higher temperatures and longer heating. In one trial, with about 2 feet of cut stalks, cottonseed meal, and limestone, the temperature in the cornstalks was maintained at 90 degrees or above for fully 2 months. In another, started March 10, 1930, with cornstalks and cottonseed meal, the temperature was, on March 13, 120 to 130 degrees; on April 15, 90 to 100 degrees; and on April 30, 80 to 90 degrees F.

Heat development was tested by treating cornstalks in a series of beds as follows: (1) 5 pounds cottonseed meal, (2) 5 pounds cottonseed meal and 5 pounds ground limestone, (3) 10 pounds cottonseed meal and 5 pounds ground limestone, (4) cornstalks alone, and (5) 5 pounds cottonseed meal, 5 pounds ground limestone, and 2 pounds superphosphate.

On October 29, the stalks were cut and tramped in 2-inch layers, with the various additional treatments spread over each layer, until a depth of 12 to 15 inches was reached. Four inches of soil was placed on them and watered at the rate of about 1 gallon of water per cubic foot of cornstalks. Each bed was the size of a standard hotbed sash (3 x 6 feet). Table I gives the temperature at the juncture of the soil and stalks and in the air under the sash. The table shows that cottonseed meal and superphosphate caused the highest temperatures. Limestone did not raise the temperature, but it seems well to use it in order to enhance nitrification.

Sodium carbonate at about 1 to 2 pounds per sash, with lime-

[1]The investigation reported in this paper is in connection with a project of the Kentucky Agricultural Experiment Station and is published by permission of the Director.

stone, was used in several trials. The heating was not increased, but the cornstalks were much more completely rotted and proved to be in good shape to use as fertilizer. Much nitrate was present and there were indications of fixation of nitrogen from the air, altho no definite data were obtained to prove this point. References

TABLE I—HOTBED TEMPERATURES PRODUCED BY FERMENTING CORNSTALKS

Date 1930	Minimum Temperature Outside Air (Degrees F)	Inside Air Temperature (Degrees F)		Temperature at Juncture of Soil and Stalks in Beds of Stalks Variously Treated (Degrees F)				
		Max.	Min.	5 CS Meal	5 CS Meal 5 Lime	10 CS Meal 5 Lime	No Treatment	5 CS Meal 5 Lime 2 Phos.
Oct. 30..	36	88	42	64	74	74	76	76
Nov. 3...	44	70	58	78	78	78	82	88
Nov. 4...	—	72	54	80	78	78	76	80
Nov. 5...	33	76	44	74	76	80	72	80
Nov. 6...	42	78	48	80	72	78	74	79
Nov. 7..	58	74	48	82	78	78	78	82
Nov. 14..	34	78	38	79	80	76	74	78
Nov. 20 .	28	75	36	80	84	72	77	87
Nov. 30 .	50	—	—	78	74	72	70	80
Dec. 6*..	17	—	30	77	77	76	74	81
Dec. 11..	24	—	30	70	65	62	—	—

*Used a small lamp during this night.

cited and results presented in a previous publication (2) show that an alkaline reaction is very favorable to both nitrification and nitrogen fixation. The presence of organic matter enhances the action of azotobacter. These results justify the assumption that nitrogen conditions would be favored in the cornstalk hotbeds by lime and sodium carbonate. Albrecht (1) finds limestone essential in the production of good artificial manure from straw. In the presence of large amounts of cellulose and soil absorptive agents no ammonia is likely to be lost from the alkaline reaction created.

Lettuce, spinach, radishes, onions, and celery were grown. The celery was set in January, after radishes and spinach, and was large enough to use in April, having grown slowly during January and February. Only a small part went to seed, the rest being of good size and quality. The lettuce, spinach, onions, and radishes were set or planted October 30. The spinach and radishes did not do well. The spinach was affected with mildew and the radishes "went to top." The onions did well. Most of the frame was set to lettuce. On January 5, good, solid heads of New York lettuce were harvested. Iceberg lettuce produced large heads, but they lacked solidity. Grand Rapids lettuce did well. In another trial, both tomato plants and mature tomato fruits were satisfactorily produced with cornstalks as a source of heat, when started about the middle of March.

Recommended Procedure for Making a Cornstalk Hotbed

Make the hotbed the same as for manure but about 6 inches deeper. Cut the stalks to 1- to 2-inch lengths and tramp in until about 2 inches deep, spread about ½ pound of cottonseed meal per sash on this layer, and repeat until about 12 to 18 inches deep. The depth should vary with the weather expected and the amount of heat desired. If 12 inches of manure usually are used, about 18 inches of stalks should be used. Limestone, sodium carbonate, and phosphate may be used if desired. They are especially valuable where plants are to remain a long time or are to be matured and the roots allowed to grow into the cornstalks or where the stalks are to be used as manure. Good results can be obtained with cornstalks alone.

One of the difficulties is in thoroughly soaking the stalks. There are three possibilities. (1) The most efficient is soaking the stalks in barrels before placing in the bed. (2) The beds may be soaked with water from a hose. In applying water with a hose the water tends to run through the stalks. If the soil is put on and water applied through this, better results are obtained. Long, thorough soaking is necessary. (3) If the bed is made up before a rain or a considerable time before needed, rain may usually be depended on to thoroughly wet the mass of stalks.

About 4 inches of soil should be used. Plants should be set or seeds planted as soon as the heat is about 70 degrees F in the stalks. There is no danger of overheating.

The advantages of the cornstalk hotbed are: (1) It does not become too hot, (2) no heat is wasted as in the excessive stages of manure heating, (3) there is no injury from fumes, (4) heat lasts for one to two months, (5) the heat is uniform, (6) cornstalks usually are cheap and readily obtainable, and (7) rotted cornstalks, especially when cottonseed meal, sodium carbonate, superphosphate, and limestone were used, are a good substitute for manure as a fertilizer.

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Some Results on the Pruning, Topping and Staking of the Marglobe Tomato

By J. B. EDMOND, *Mississippi State College, State College, Miss.*[1]

THE results of effects of pruning and staking on yield of tomatoes, though numerous, have been somewhat contradictory. Since investigators have used different varieties, cultural practices, planting distances, systems of training, and harvesting periods, and since the experiments have been conducted in regions varying widely in soils and in climate, the marked inconsistency in the results is not surprising. Apparently, results secured in one locality do not necessarily apply to another. The results of preliminary tests conducted in 1932 on the pruning and staking of tomatoes, as practiced by Mississippi growers, are reported herein.

The plants were raised in an experimental house of the Department of Horticulture, State College, Mississippi. Seed was planted January 30 in flats containing a mixture of one-half coarse sand and one-half compost. To insure good germination bottom heat was supplied, maintaining a temperature of 60 to 65 degrees F. On February 13, the seedlings were transplanted 2½ x 2½ inches in flats containing garden loam, and on March 14 they were transplanted 4 x 4 inches in other flats. On April 9 they were set in the field 4 feet apart in rows 4 feet apart. Height of plants at this time varied from 8 to 12 inches.

The experimental area, consisting of heavily manured, spray irrigated Ocklocknee clay loam, was 168 feet long and 26 feet wide. It sufficed for the lengthwise planting of five rows. Records were taken from the two inside rows only, namely, the pruned row designated Plot A and the unpruned row designated Plot B. The plants in all rows except those in the unpruned row (Plot B) were trained to a single stem, staked and topped at the fourth cluster.

Since Hoffman (1) observed that vigor of growth, induced by applications of $NaNO_3$, is associated with early yield, applications of $NaNO_3$, complete mixtures, or water were made to promote vigor and steady growth and to minimize the development of blossom end rot. However, marked differences in vigor of growth were observed between the two lots. The pruned plants, even though they received lesser quantities of commercial fertilizers, possessed darker foliage, larger leaves and thicker stems.

Pruning was begun on April 21 when the laterals arising from the first six nodes were pinched off and continued until the flowers of the fourth cluster were in bud stage. At this time the terminal axis was pinched off. The plants except those in Plot B were staked on May 4.

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[1]Published with permission of the Director of the Mississippi Station. The writer is indebted to Professor R. V. Lott for reviewing the manuscript.

TABLE I—EFFECT OF PRUNING, TOPPING, AND STAKING ON YIELD OF THE MARGLOBE TOMATO—1932

Treatment	Harvest Dates							May 30 to June 29
	May 30	June 3	June 7	June 13	June 16	June 22	June 29	
Average Number Marketable Fruit per Plant								
Pruned, Topped, Staked[1] (Plot A)	2.2±.11	1.6±.12	0.6±.09	1.8±.15	2.3±.18	1.3±.16	1.7±.09	11.5±.31
Unpruned, Untopped, Unstaked[2] (Plot B)	2.6±.14	0.7±.19	1.0±.15	0.9±.17	0.6±.13	0.5±.14	4.7±.47	11.0±.34
Difference (A minus B)	—0.4±.18†	0.9±.23*	—0.4±.17†	0.9±.23*	1.7±.22*	0.8±.22*	—3.0±.48*	0.5±.46†
Average Weight (Ozs.) Marketable Fruit								
Pruned, Topped, Staked (Plot A)	4.9±.09	4.5±.10	5.1±.19	5.6±.07	4.7±.09	4.3±.09	3.7±.11	4.6±.03
Unpruned, Untopped, Unstaked (Plot B)	4.0±.06	3.1±.19	3.7±.14	3.6±.16	2.7±.17	4.1±.14	3.3±.04	3.5±.03
Difference (A minus B)	0.9±.11*	1.4±.22*	1.4±.17*	2.0±.17*	2.0±.18*	0.2±.17†	0.4±.12*	1.1±.05*

[1]39 plants. [2]20 plants.
*Differences are considered significant. †Differences are considered insignificant.

Harvesting was begun on May 30 and continued at intervals of 3 to 6 days until June 29 when practically all fruits had matured on the fourth clusters of the pruned plants. The fruits were picked in the green-mature state of maturity, as indicated by the characteristic browning of the abscission zone. Data are recorded on average weight of marketable fruit and on the average number of fruits per plant for each picking date. All unmarketable fruits on healthy uniformly vigorous plants and yields of plants showing lack of vigor or evidence of Fusarium wilt were discarded.

The data presented in Table I show that the pruned plants produced significantly more fruits for the June 3, 13, 16, and 22 harvests, respectively, and that the unpruned, untopped plants produced more fruits for the May 30, June 7, and 29 harvests, the initial, third, and final dates of harvesting. These differences are significant for the final harvesting date only. Since pruning and topping markedly reduced vegetative growth, the reproductive phase of growth was accordingly stimulated. In this way the pruned plants produced more fruits during the usual shipping period of Mississippi tomatoes than the unpruned plants. This is a matter of considerable importance. Shipments from Texas usually begin to decline about the first week in June while those from Tennessee begin about the last week in June. To avoid severe competition from these districts shipments from Mississippi should begin about the first week in June and should end about the first week in July. Apparently pruning to a single stem and topping at the fourth cluster is more likely to facilitate the production of relatively greater quantities of fruit during the period when supplies from competing sections are light than nonpruning and nontopping.

The results show that since the unpruned, untopped plants produced far greater yields on the final harvesting date (June 29) than on any preceding harvest, nonpruning should not be expected to produce greater yields than pruning until the fourth week of the harvesting period, at least under the conditions of this experiment. Magruder (2) obtained similar results with a strain of Livingston's Globe. He found that pruned plants outyielded the nonpruned plants during the first 4 weeks of the harvesting period, while the nonpruned plants outyielded the pruned plants during the fifth, sixth, and seventh weeks of the harvesting period.

The data show that with the exception of the June 22 harvest pruning significantly increased fruit size, as measured by fresh weight. For either treatment variation in size during the picking season was dissimilar. Fruit of the pruned plants attained the largest size at the June 13 harvest, after which a gradual decline took place, while that of the nonpruned plants attained the largest size on the June 22 harvest. Since production of large sized fruits is desirable and since pruning increases size as well as yield during the first three weeks of harvesting, the desirability of the practice is correspondingly increased.

TABLE II—EFFECT OF PRUNING, TOPPING, AND STAKING ON FLOWER AND FRUIT PRODUCTION PER CLUSTER OF THE MARGLOBE TOMATO—1932

Treatment	Number of Cluster							
	First		Second		Third		Fourth	
	Flowers	Fruit[3]	Flowers	Fruit	Flowers	Fruit	Flowers	Fruit
Pruned, Topped, Staked[1] (Plot A)	6.1±.23	5.6±.19	6.4±.21	5.7±.11	6.2±.16	4.6±.13	6.4±.13	4.7±.18
Unpruned, Untopped, Unstaked[2] (Plot B)	5.3±.25	3.3±.21	5.3±.20	2.9±.20	4.5±.16	2.3±.18	4.7±.17	2.3±.12
Difference (A minus B)	0.8±.34†	2.3±.28*	1.1±.29*	2.8±.22*	1.7±.22*	2.3±.22*	1.7±.28*	2.4±.22
	Percentage Flowers Setting Fruit							
Pruned, Topped, Staked (Plot A)	91.8		88.4		73.9		73.3	
Unpruned, Untopped, Unstaked (Plot B)	63.1		54.7		51.4		49.4	
Difference (A minus B)	28.7		33.7		22.5		23.9	

[1]39 plants. [2]20 plants [3]All fruits.
*Differences are considered significant. †Differences are considered insignificant.

The data in Table II show that pruning and topping not only increased the number of blossoms and fruits per cluster but also increased the percentage of set. The percentage differences in the setting of fruits per cluster is particularly striking. On the pruned plants from 73 to 92 per cent of the flowers set fruit, while on the unpruned plants from 49 to 63 per cent set fruit. In both cases the percentage of flowers setting fruit was highest for the first cluster and gradually declined to the fourth cluster. Other investigators have observed that pruning increases the percentage of fruit set. As Jones and Rosa (3) have pointed out, since pruning limits the vegetative growth of the plant, carbohydrate content is increased, which is undoubtedly associated with if not directly related to the production of flowers and setting of fruit.

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Linkage Relations of Growth Habit in Tomato Plants[1]

By T. M. Currence, *University of Minnesota, St. Paul, Minn.*

THE designation "determinate growth habit" describes a characteristic of certain tomato plants which are popularly known as self-pruning types. In the early stages of growth it is not possible to distinguish between the determinate and indeterminate plants, but after fruits have begun to develop there is a marked difference between the two forms. The determinate-plants show a profuse amount of flowering and relatively little vegetative growth. The shoots do not actually terminate in a flower cluster as the term might suggest, but the development of the flowers seems to dominate that of the vegetative shoot. This condition appears to affect the older shoots and therefore vegetative branches can always be found on the plant. Data taken at University Farm on the inheritance and linkage relations of this character are fairly complete and may be of interest in supplementing the material published by others.

Yeager (5) describing self-pruning plants states that the character behaves as a simple mendelian. McArthur (4), in studying the genetics of the character, found the gene to be linked with that for potato leaf with a crossover percentage of 17.

Inheritance of Growth Habit

A determinate plant was crossed with two plants that were homozygous for indeterminate habit. From the F_2 of one of these crosses, 372 plants were indeterminate and 101 were determinate. This is a deviation of 17 ± 6.4. From the other cross 447 plants were indeterminate and 126 were classified as determinate. This deviation is 17 ± 7.0. When an F_1 plant was crossed with the determinate parent, 67 indeterminate and 71 determinate plants were obtained. The deviation is 2 ± 4.0. These figures are considered to indicate definitely that the character is a simple mendelian and that determinate is recessive to indeterminate.

Linkage Relations

The characters and factors concerned in the linkage study are given in the following list:

d, dwarf plant recessive to standard type or D.
r, yellow flesh recessive to pink flesh or R.
y, colorless skin recessive to pigmented skin or Y.
c, potato leaf recessive to normal leaf or C.
t, Determinate growth habit recessive to indeterminate or T.

[1]Journal Series Paper No. 1133 of the Minnesota Agricultural Experiment Station.

f, fasciated fruit recessive to non-fasciated or F.
a, green stem recessive to purple stem or A.
l. lutescent foliage recessive to normal green foliage or L.

The indeterminate plants are designated as 57 and 58 and the determinate strain at 30.[3] The genotype of strain 57 is yyccaall; of 58, ddrryyff; and of 30, fftt. These recessives mark six of the chromosome pairs.

The linkage data from the F_2 and backcross generation are given in Table I. The method used for calculating the F_2 recombination values is that given by Fisher and Balmukand (3). It is obvious from the F_2 results that linkage is present between the factor for growth habit and the leaf type factor. As shown by the table, the double recessive was not obtained in the F_2 generation and it was therefore necessary to grow an F_3. The Ct phenotype was used for this and progenies were grown from 101 F_2 plants of this type. With random assortment of the two factors, the genotype ratio of approximately 2 Cctt: 1 CCtt would be expected; the actual figures are 4 Cctt : 97 CCtt. This indicates a close linkage for the two genes with approximately 2 per cent crossing over. The double recessive type obtained in this way was used for backcrossing.

TABLE I—Linkage Relations Between T and Other Factors

Genes XY	Linkage Phase	Phenotypes Number of Individuals[2] XY	Xy	xY	xy	Total	Recombination Value
T D	R F_2	338	96	101	29	564	.502±.021
T R	R F_2	297	84	82	29	492	.531±.022
T Y[1]	R F_2	558	185	164	50	957	.488±.017
T C	R F_2	257	105	103	0	465	
T C	R Bc	4	79	77	2	162	.037±.008
T F	C F_2	271	93	72	29	465	.478±.023
T F	C Bc	29	38	36	35	138	.536±.029
T L	R F_2	310	52	92	11	465	.452±.025
T A	R F_2	276	86	85	18	465	.446±.025

[1]Data from both crosses.
[2]Xx represents Tt and Yy, the other factor pair.

The backcross population was made up of 162 plants. Six of these occurred in the crossover groups. The crossover percentage shown by these figures, therefore, is 3.7 ± 0.8. The disagreement between this result and that obtained by McArthur may be accounted for by the fact that his calculation was made on an F_2 from a cross in the repulsion phase.[8]

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[3]The writer is indebted to Dr. J. W. McArthur for the original seed of strains 57 and 58.

[8]Data published by McArthur appearing since this paper was submitted for publication are essentially in agreement with those given here. (Jour. Hered. 23: 395–396. 1932.)

Based on the F_3 and backcross data that have been given, the conclusion may be made that determinate growth habit is linked with leaf type with a crossover value of from 2 to 4 per cent.

Association Between Growth Habit and Quantitative Characters

The possibility that determinate plants tend to be earlier, due to the more exposed position of the fruit has been suggested. The two indeterminate strains which were crossed with the determinate one were distinctly later in maturing fruit. It seemed desirable, therefore, to compare the two types of plants for earliness as they segregated after crossing. In this way any relationship between growth habit and time of fruiting should be indicated. In classifying the plants the number of days elapsing after a certain date (July 20) before ripe fruit developed were recorded. By calculating the mean number of days comparisons could be made.

TABLE II—Time of Ripening Fruit of Determinate and Indeterminate Plants for Parental, F_2 and Backcross Populations

Generation and Cross	Growth Habit	No. Plants Classified	Fruit Ripening Mean	Difference
P_1, 30	Determinate	63	21.4 ±0.7	
P_1, 57	Indeterminate	60	28.4 ±0.7	
P_1, 58	Indeterminate	66	29.1 ±0.6	
F_2 30x57	Determinate	99	18.5 ±0.45	
F_2 30x57	Indeterminate	352	20.4 ±0.25	1.9±0.51
F_2 30x58	Determinate	126	20.1 ±0.37	
F_2 30x58	Indeterminate	447	21.5 ±0.25	1.4 ±0.45
Bc (30x57)x30	Determinate	71	14.87±0.41	
Bc (30x57)x30	Indeterminate	67	15.85±0.41	0.98±0.58

The means with differences calculated are given in Table II. It is apparent that there was a distinct tendency for the determinate plants to ripen earlier in both F_2 groups and in the one backcross population available. Though the difference for the backcross is small and less than twice its probable error, it is in agreement with the F_2 data which are statistically significant.

The data do not answer the question as to whether or not the results are due to the gene for growth habit or to other genes in the same chromosome. Late determinate plants were obtained and early indeterminate ones also, but it was not possible to determine definitely whether or not they were crossover individuals.

Relation Between Size of Fruit and Growth Habit

The indeterminate strain 57 was very small-fruited as compared to the determinate strain. The cross between these two provided an opportunity to make a study on fruit size similar to that made on earliness. In the F_2 population the determinate plants gave an average fruit size of 72 ± 2.27 gms and the indeterminate fruit

size was 66 ± 1.09 gms. The difference is 6 ± 2.52 gms. In the backcross group the determinate and indeterminate plants gave means 106 ± 3.89 and 102 ± 4.17, respectively. The difference is 4 ± 5.70. Although neither of these differences is statistically significant they may have some importance since both populations are in agreement and the differences are in the same relation as they exist in the paternal strains. However, the data do not indicate that important factors for fruit size were associated with the growth habit gene in the cross.

Summary

Plants with determinate growth habit tend to develop a limited amount of vegetative growth with profuse flowering and fruiting. The data obtained indicate simple mendelian inheritance for the character. and the gene to be linked with that for leaf type. Based on F_3 and backcross results, the crossover value is from 2 to 4 per cent.

Early ripening of fruit and determinate growth habit tended to remain together after crossing. The determinate plants may be earlier because the fruit is borne in exposed positions or there may be other genetic factors in the same chromosome which affect earliness.

Fruit size showed a tendency to be associated with growth habit, but the data do not establish this point.

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Some Factors Affecting the Wholeness of Canned Tomatoes

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WHOLENESS of canned tomatoes (or similarity to the form of fresh tomatoes) is considered of equal importance with color in grading of tomatoes. Methods of picking, handling, peeling, and other mechanical operations affect the physical wholeness of the product. The changing of the pectin-protopectin content (1), and the transverse breaking of the cell walls (2) due to maturity, processing, and storage will result in chemical changes and affect wholeness. These latter changes are more likely to result in a softness and mushiness of the product. There seems little chance that conditions preventing protopectin changes, cell wall breakage, or that more favorable environmental conditions will greatly improve the wholeness of canned tomatoes until more care is used in mechanical operations to lessen the physical breaking of the tomatoes.

Method of Study

Variety: It was believed a study of the loss in weight of the fruit, as well as its change in shape, would give a satisfactory index of change in wholeness. Tomatoes after being peeled in the factory were weighed, and the greatest and least diameters obtained, as well as the stem to blossom end (polar) diameter. The same data were obtained after the fruit had been removed from the sealed can. The processed tomatoes were weighed after being placed on a wire screen (6 meshes to the linear inch) and drained for 2 minutes. The following formula gives the method used to determine the change in shape:

$$\frac{(Gc + Lc) \times 2\ Pr}{(Gr + Lr) \times 2\ Pc} = \text{Ratio of change in shape.}$$

G—greatest diameter.
L—least diameter.
P—polar diameter.
c—canned product.
r—raw stock.

If there has been no change in shape it would be indicated by one (1.00), and the proportion of flattening out is determined by the magnitude by which the number is greater than one. The change in weight was expressed by the percentage loss. Number 2 cans were used in these experiments.

Peeling: With the adoption of the purchase of raw stock on the basis of Federal-State grades it was possible to obtain information as to the quality of the raw stock purchased at different factories. This permitted an examination of the care used in peeling tomatoes by various women in various factories, making the study on the

basis of the quality of the raw stock. Six factories were visited during 1928 and 1929 and each peeler's receptacle was graded on a basis as similar as possible to the U. S. Department of Agriculture. Federal Warehouse grades for canned tomatoes. It was impractical to give consideration to flavor and drained weight. About equal weight was given to the factors of color, wholeness, and freedom from defects. Color was not affected by peeling, but it was a necessary consideration from the standpoint of the grades on the raw stock. Defects such as skin and core are almost wholly within the control of the peelers.

Results

Effect of Variety and Factory Methods on Breakdown: Raw stock was used which was whole and had not been submitted to a large amount of unnecessary bruising. The tomatoes used in 1926 and the first tested in 1927 were very carefully peeled while the second experiment in 1927 was not so carefully peeled. In 1926 (Table I), both on the basis of loss in weight and change in shape, there was a distinct difference between Indiana Baltimore and Marglobe. The first test in 1927 gave some distinct differences between varieties, but the second test gave practically no significant results.

TABLE I—Effect of Variety on the Wholeness of Canned Tomatoes

Variety	Mean Percentage Loss of Weight of Individual Fruits			Mean Change in Shape of Individual Fruits		
	1926	1927	1927*	1926	1927	1927*
Indiana Baltimore..	17.3±1.10	7.73±.137	20.8±.344	1.83±.05	1.40±.006	1.82±.017
Marglobe	29.6±.96	20.0±.244	21.7±.351	2.94±.25	1.82±.021	2.25±.030
Glory ...		9.58±.180	19.2±.213	——	1.32±.008	1.50±.007
Chalk's Jewel		22.1±.297	22.1±.207	——	1.85±.018	1.57±.011

*Tomatoes not so carefully peeled as in the preceding two tests.

In order to determine the effects of certain methods of handling canned tomatoes some further tests were made. In 1925 canned tomatoes were subjected to 25-, 35-, and 45-minute processing in boiling water and were cooled either in water or air. Water cooling gave less change at 25 minutes than air cooling, while at 45 minutes there was less difference between the two treatments. Data are given in Table II relative to the tests in 1926. These data show consistent effects of length of sterilization and method of cooling. The 1925 product was shipped from the canning factory to Lafayette by interurban, and the 1926 cans were transported by automobile.

In 1927, there were found little or no difference in wholeness between sterilization in a continuous steam cooker and an open kettle at the temperature of boiling water. Cans at this factory were

rolled back to warehouse on tracks. Test cans were rolled back once and others five times without any important differences.

Although this work has given some significant differences, these are not large compared to those found in the variation in workmanship in peeling.

TABLE II—EFFECT OF LENGTH OF STERILIZATION AND METHOD OF COOLING ON THE WHOLENESS OF CANNED TOMATOES (1926)

Variety	Time of Sterilization (Minutes)	Loss of Weight (Per cent)		Change in Shape Ratio	
		Water Cooled	Air Cooled	Water Cooled	Air Cooled
Indiana Baltimore.......	30	17.3±1.10	26.4±1.23	1.83±.05	2.15±.10
	60	23.1±1.30	30.9±1.24	1.98±.10	2.33±.12
Marglobe.....	30	29.6± .96	———	2.94±.25	———
	60	42.2±1.59	———	4.43±.31	———

Quality as Affected by Peeling: Among the several factors which may affect the wholeness in canned tomatoes, it was thought advisable to consider the comparative treatment by different peelers. The mere fact that cans of tomatoes when opened contain a large number of pieces does not prove this is due to processing or variety, but may be due to their being placed in the can in pieces. With Federal-State inspection of the raw stock it was possible to have some uniform basis for comparing the different factories. There was no way of obtaining the exact raw product grade, so the grade for the whole day was used, although the work may have been confined to one-half day. Tomato peelers are practically always paid so much per bucket with rarely a bonus for good workmanship. The women are hired over a short period and, consequently, it is impossible to be very selective as to the peelers employed. All the factories in Table II canned tomatoes and made pulp except factory 4 which canned only tomatoes.

An examination of the figures in Table III shows great differences between the factories, especially factories 1 and 5 as compared to factory 4. Factories 1 and 5 are located in regions that produce a very large proportion of Standard grade of canned tomatoes and the peelers were not strictly supervised. In the case of factory 4 the contracted acreage was small and the factory manager gave the peelers close supervision. It would seem from these figures that care used in peeling tomatoes is important. The differences due to variety, sterilization time, and method of cooling are small in comparison to the change due to manner of handling during peeling. It may seem absurd that at factory 4 in 1928 there were more fancy tomatoes canned than U. S. No. 1's purchased, but it should be remembered that in the grading of the peeled product equal weight was given to color, wholeness, and defects. The grader of the raw stock considered color, but gave little or no weight to wholeness and defects of peeling.

TABLE III—Grades of Peeled Tomatoes 1928 and 1929

No. Canning Factory	Date	Grade of Peeled Tomatoes (Per cent)			U. S. Grade of Raw Stock (Per cent)			Relation of Raw Stock to Peeled Stock	
		Fancy	Extra Stand-ard	Stand-ard	No. 1	No. 2	Culls	Percentage Fancy from No. 1 Tomatoes	Percentage of Fancy and Extra Stand-ard from No. 1 and No. 2 Tomatoes
					(1928)				
1	9/12	0.4	9.1	90.5	49.9	45.6	4.5	0.8	9.95
2	9/20	6.3	25.5	68.2	25.9	62.7	11.4	24.3	35.9
3	9/21	5.4	26.6	68	56.8	37.8	5.4	9.5	33.8
	9/22	6.0	28	66	56.3	38.7	5.0	10.7	35.8
4	9/8	19.5	33.5	47.0	35.5	51.7	12.8	55.0	60.8
	9/13	19.6	32.0	48.4	38.6	48.1	13.3	50.8	59.5
	9/27	32.1	37.8	30.1	26.7	45.0	28.3	120.5	97.5
					(1929)				
1	9/10	2.2	15.7	82.1	37.8	60.6	1.6	5.8	18.2
5	9/10	0.5	20.0	79.5	64.6	35.2	0.2	0.8	20.6
4	9/11	16.5	27.4	56.1	37.7	42.8	19.5	43.8	54.5
6	9/14	18.1	32.9	49.0	66.8	32.0	1.2	26.7	51.6

Further evidence on this same point can be obtained from the relative amount of juice to peeled meat at two of these factories In poor peeling the seed cells are cut open and the juice runs out. At factory 1 there was found 7 pounds of solid tomatoes in the peeling pails to 1 pound of juice, while at factory 4 there was 64 pounds of meat to 1 pound of juice.

In many factories the scalded tomatoes are put on an endless rubber belt so it would seem that the women nearest the head end of the belt, having a choice of the tomatoes, would have the best grading tomatoes. The figures of 1928 were examined from this standpoint with little evidence that this was true. In factory 1, the woman peeling the highest percentage of fancy tomatoes and the woman peeling the lowest were opposite each other and occupied the second position on the belt from the front. The same was true of factory 3 on one day when similarly ranking workers were fourth from the front. Another day the poorest peeler was 9 positions ahead of the best peeler. This is further evidence that the wholeness of tomatoes cannot be preserved unless the work in the factory is accurately controlled. It seems reasonable to believe that some disintegration may be due to the use of automatic machinery. Where tomatoes are placed in the cans whole and carefully handled there is little difficulty in obtaining a product desirable from the standpoint of wholeness.

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Observations on Flower Bud and Pod Development in Okra

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ALTHOUGH okra is a popular vegetable in home gardens in the South and is of considerable importance as a truck, market garden and canning crop, it has never received much attention from the investigator. It has for some time been the aim of the senior author to make a rather thorough study of the okra plant, particularly as to its morphology and certain phases of its genetic behavior. In the preliminary studies certain observations have been made which are thought to be of sufficient interest to present here.

Normally, the okra plant consists of a central stem with one or more branches arising from near its base. The branches may be short or they may approximate the central stem in length.

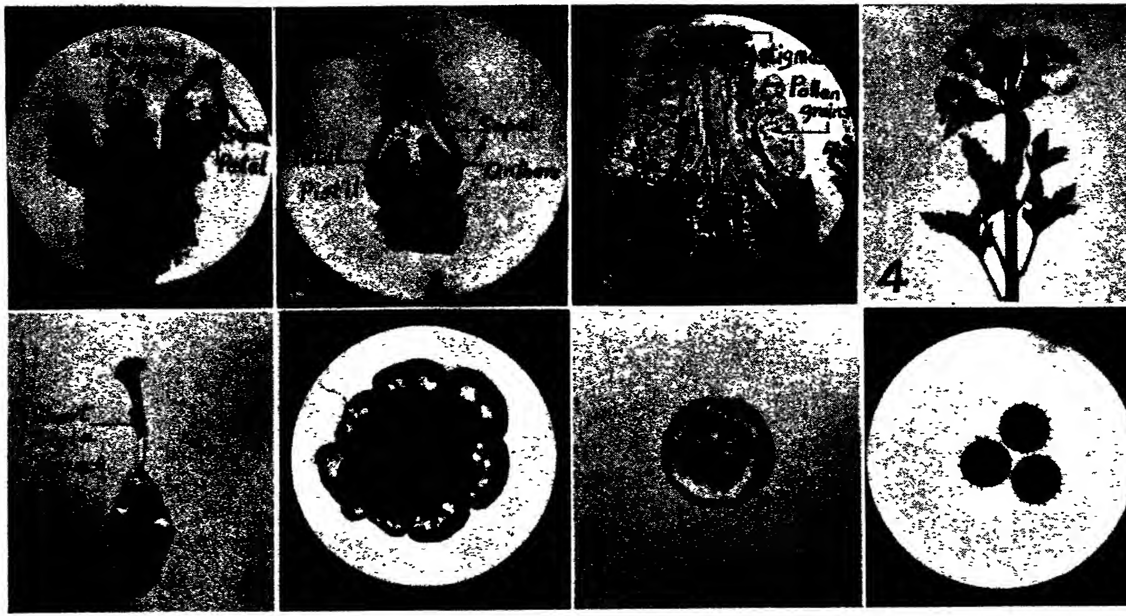
Except for a few nodes (six to eight) at the base of the plant, a flower bud occurs normally at each node on both the central stem and branches. The fruiting period usually begins in early summer and continues until late in the fall. At any time during this period there will be found at the apex of each stem, a cluster of some 8 to 15 buds varying in size from the smallest which can be distinguished with the naked eye to those which are ready to open. Under good growing conditions these buds open at the rate of one every 2 or 3 days. In cool weather, development may be much slower. Plate I, Figs. 1–4, show the course of development of the flower buds. Normally about 25 days intervene between differentiation and blooming.

TABLE I—Number of Carpels in Okra Pods

Variety	Location	Number Pods Examined	Number Pods Having Indicated No. Carpels (5–10)					
			5	6	7	8	9	10
White Velvet	So. Carolina	105	75	19	6	5	—	—
White Velvet	Oklahoma	99	26	26	29	13	5	—
Perkins	So. Carolina	103	1	15	61	19	5	2
Perkins	Oklahoma	100	1	20	33	33	12	1
Dwarf Green Prolific	So. Carolina	81	—	6	19	37	11	8
Dwarf Green Prolific	Oklahoma	100	—	5	21	35	25	14
Spineless Strain	So. Carolina	100	12	34	32	15	7	—

There are several facts in connection with pod development which have been noted. Bailey (1) and Robbins (2) both state that okra has a 5-celled ovary with five style branches. During this study, the number of carpels in a considerable number of pods of several varieties was determined. The record is given in Table I. (See also Plate I, Figs. 6 and 7.)

PLATE I.



(1) Section through end of okra stem. (2) Flower bud, 8–10 days before bloom. (3) Flower bud near blooming stage. (4) Three flowers open on single stem. (5) Pistil with short style branch which may result in sterile carpel. (6) Cross-section of style with seven branches. (7) Cross-section of young pod with seven carpels in a 5-sided structure. (8) Pollen grains, × 20.

The varieties included in this list cover the range of types of okra in existence in this country. Each variety seems to have its own characteristic distribution of carpel numbers. If the descriptions (as to carpel number) of Bailey and Robbins, referred to above, applied to the original type, then there has been considerable variation under cultivation.

Woodroof (3) states that never more than one flower occurs upon a stem in any one day. Plate I, Fig. 4 shows a stem on which three flowers opened simultaneously. A number of other cases were observed where two flowers per stem opened the same day.

Plate I, Fig. 5, shows a pistil with a short style branch which would probably have resulted in a sterile carpel. The unusually large pollen grains are shown in Plate I, Fig. 8.

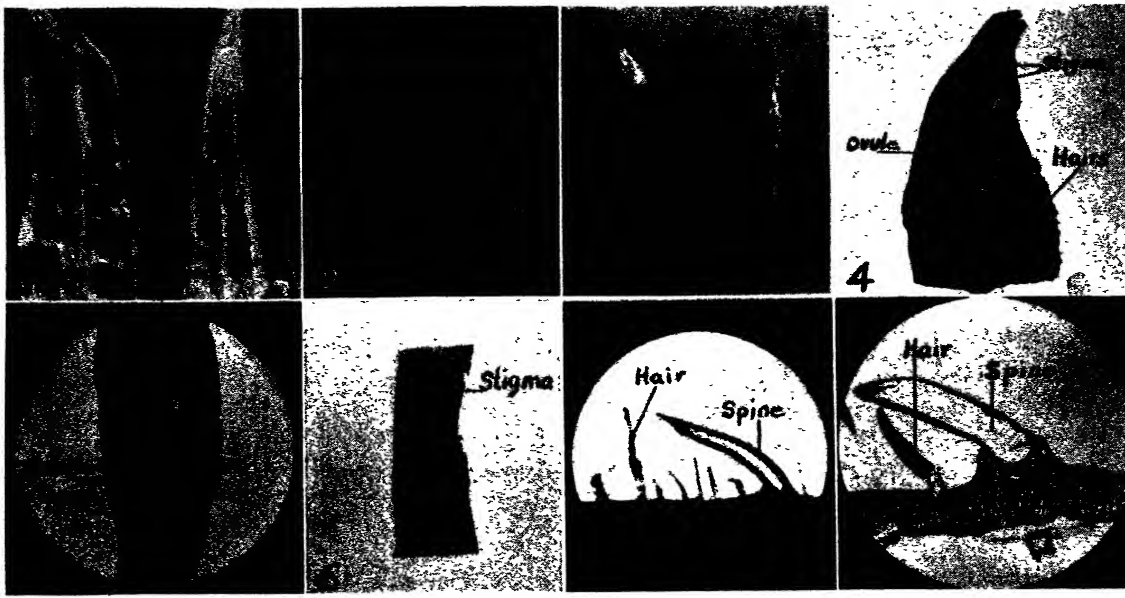
Harris (4) noted, several years ago, an abnormality of okra pods which he termed "prolification." More recently, Bergman (5) has described what he calls "intracarpellary fruits" in certain species of hibiscus, which occur in the Hawaiian Islands. The writers have also observed numerous structures of the type referred to by Harris and Bergman in connection with this study. Apparently the term "*inter*-carpellary fruit" or "intercarpellary pistil" is preferable to "*intra*-carpellary fruit" in the cases discussed herein, since the structure occurs between the carpels and not within them. Another term which has been suggested is "supernumerary abortive ovaries."

Plate II, Figs. 1, 2, and 3 show examples of these abnormalities. They are imbedded in the tissue which forms the central axis of the pod. In the early stages they are green in color, pubescent, and have well-developed ovules, styles and stigmas. As many as four of these structures have been found in one pod, and in a few cases have attained sufficient size to split the pod. As Harris states, it is difficult to say whether they have a connection with the torus or with the carpellary margins. The former seems most likely from this study, although further work will be necessary to establish the point definitely. Bergman found connection with the torus "very apparent in all specimens" examined by him.

Plate II, Figs. 4 and 5, are longitudinal sections through one of these structures. In Fig. 6 is seen an earlier stage. Observations made in this study indicate that the frequency of occurrence of these intercarpellary fruits and the degree of development attained depends upon the variety of okra and possibly upon climatic conditions. Counts at Ithaca, New York, showed that the following percentage of pods, of the varieties indicated, were affected with this abnormality.

Variety	Percentage of Pods Having Intercarpellary Fruits
Dwarf Green Prolific	47.8
Kleckley's Favorite	44.0
White Velvet	25.6
Dwarf	13.6
Perkins, Strain 1	13.1
Perkins, Strain 2	10.3
Spineless	13.3

PLATE II.



(1) (2) Okra pods containing intercarpellary pistils. Note that style branches are separated (not compound) in these cases. (3) Intercarpellary pistils removed from pods. Specimen at right includes three of these pistils, one above the other. (4) Longitudinal section through intercarpellary pistil. (5) Lower portion of 4. (6) Early stage of an intercarpellary pistil. (7) (8) Hairs and spines from pods.

There is some indication that cool temperatures encourage the development of these structures; however, they also occur during the hottest weather. Bergman (5) says that they occur only in hybrid material, "...plants resulting from crosses of definite parents," and "is probably due to inharmonious elements or factors in the gametes derived from parents of different species." The observations reported here do not support this idea, since many pods of White Velvet and Dwarf Green Prolific, both rather stable varieties, showed the presence of the abnormality.

Other abnormalities which have been observed are: (1) pods developing without seeds, (2) the presence of two to four whorls of bracts (instead of one) at base of flower, and (3) flowers consisting of pistils only. In the latter case, some of the bracts had developed to abnormally large size, and the style was much more distinctly branched than usual.

The spines and hairs which are found upon all parts of okra plants have also been studied. Plate II, Figs. 7 and 8, illustrate these structures as found upon okra pods. The hairs are multicellular and obviously arise from epidermal cells. The spines are single cells with thick walls. Their exact mode of development is not definitely known since no early stages have been observed in the numerous slides examined. It does not seem likely, however, that they develop from hairs.

The hairs, but not the spines, can be seen within the flower bud, some time in advance of blooming (Plate I, Fig. 3). The cause of the stinging produced by the spines may be purely mechanical or it may be chemical. Some effort is being made to determine this point. Several strains of okra free from the disagreeable spines, or practically so, are being developed.

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Effect of Temperature Upon the Character of Growth of Mature Onions

By JULIAN C. MILLER, *Louisiana State University, Baton Rouge, La.*

DURING the past few years a great deal has been said and done with reference to the response of plants to length of day. Temperature is another factor which plays an important part in the morphological and physiological development of plants. It is the altering of these factors which brings into expression certain responses of plants that normally do not occur.

The earlier work of Klebs (2) and the more recent work of Thompson (4), Miller (3) and Chroboczek (1) have demonstrated that many species possess a certain characteristic range of development, but that the particular morphological phase which shall come into expression is determined by the internal conditions and activities of the plant which are largely controlled by environment.

This paper will deal with two methods of modifying the environment, namely, (1) by subjecting the plant or plant parts to environmental surroundings so that its normal growth is entirely changed; (2) by varying the time of planting, thus bringing a given stage of development of the plant under the influence of modified environment.

The work reported may be considered as two separate experiments. The first experiment was conducted while the author was connected with the Oklahoma A. & M. College. The second experiment was carried on at the Agricultural Experiment Station of the Louisiana State University and has been in progress for 3 years. The variety used in the first experiment was the Valencia and in the second experiment the Creole. All the onions were sound and free from sprouts at the time of planting.

Experiment I. On October 16, 1929, forty uniform onions were selected and stored in a laboratory where the temperature averaged about 65 degrees F. On February 15, twenty of these onions were potted to 8-inch pots and placed in a warm greenhouse, averaging 70 degrees.

The remaining twenty bulbs were allowed to remain in storage until March 16. At this time they were set to the field. The weather was still cool enough for frost to occur several times after planting. Good stocky plants developed from these bulbs and later seed-stalks emerged. A heavy crop of viable seed was produced.

The plants developing from the bulbs placed in the warm greenhouse had long and narrow leaves. These plants showed no sign of producing seed-stalks. They were allowed to grow in the greenhouse until April 24, when, since the weather was warm, it was decided to shift them to the field where they would have more room for growth. From these twenty bulbs only three small seed-stalks emerged which never developed any seed. The remaining plants

which grew from the mother bulb developed into large solid onions. From five to seven large onions developed from each of the mother bulbs.

Experiment II. The onions used in this experiment had, in each case, been harvested about May 15 of the previous season and had been kept in the curing house until November 1. At that time they were moved to a laboratory and remained there at about 65 degrees F until planted. An equal number of bulbs were counted out for each planting date. If at the successive plantings any of the onions were sprouted or showed decay, they were discarded. The cultural conditions were the same for the different plantings.

TABLE I—EFFECT OF DATE OF PLANTING ON SEED STALK OR BULB FORMATION

Planting Dates	No. Bulbs Planted	No. Seeding Plants	No. Seed Stalks per Plot	No. Bulbing Plants	Percentage Bulbing Plants
		1929–30			
Dec. 15	150	150	5.3	0	0.0
Jan. 15	146	146	5.6	0	0.0
Feb. 15	120	104	4.7	16	14.4
Mar. 15	94	11	2.1	83	89.3
		1930–31			
Dec. 15	300	300	5.2	0	0.0
Jan. 14	280	280	5.3	0	0.0
Feb. 15	220	187	3.6	33	15.0
Mar. 15	160	31	1.9	129	80.6
		1931–32			
Dec. 15	300	264	4.1	36	11.9
Jan. 15	293	236	4.8	39	13.3
Feb. 16	179	151	3.4	28	15.6
Mar. 15	133	21	1.9	112	84.2

The data from this experiment are given in Table I, which shows the number of bulbs planted and the type of growth which followed from each planting date. It will be noted that all of the bulbs of the December and January plantings of the first two years developed seed-stalks, also the third year the largest number of bulbs developing seed-stalks were from the same plantings. On the other hand, a number of the bulbs planted in February and a majority of those planted in March did not produce seed-stalks, but vegetative onion plants which later developed into mature onions. The largest number of seed-stalks per bulb were produced from the January plantings. Of the bulbs producing seed-stalks of the March planting, there was an average of 1.9 seed-stalks for each bulb planted. In many instances only one seed-stalk would develop from the mother bulb and the remaining plants from the same bulb would form onions. The three-year average for the March 15 planting shows that 84 per cent of the bulbs planted on that date produced vegetative plants and only 16 per cent of bulbs planted at the same time produced any seed-stalks at all.

The plants which produced the largest number of seed-stalks and the best set of seed were planted during December and January of 1929–30 and 1930–31. No vegetative plants developed from onions of either of these plantings. The mean temperature of this period ranged from 49 degrees to 55 degrees F and was followed by a long cool growing period. For the same years and for the same period of the February and March plantings the mean temperature ranged between 56 and 60 degrees F and was followed by a warmer growing period. The seed-stalks which developed during this period and especially those of the March planting were short and had but few flowers. The seed which formed from the flowers were in most cases faulty. Most of the onions of the February and particularly the March planting developed into vegetative plants which later formed mature onions as of the multiplying type.

The temperature for 1931–32 was considerably warmer than the two previous years, and the December and January plantings of this season developed the type of growth which occurred in the February and March planting of the two previous years. That is, most of the plants developed weak seed-stalks and many of them none at all. On the other hand, vigorous vegetative plants grew from the mother bulb and these stalks developed into mature onions.

The length of day plays a role in flower development of the onion, for regardless of the date planted all seed-stalks made their appearance between March 5 and April 10. The daily sunshine for this period was about 12.5 hours a day. Although, as shown in Experiment I and in this experiment, if the onion bulb is placed under growing conditions between 60 and 70 degrees F without a rest period at low temperature, the resultant growth will be of a vegetative nature.

It is, therefore, interesting to observe that as a result of high temperature that the onion alters its manner of reproduction, which is normally seed, to that of a vegetative multiplier. This might explain why some of the varieties of onions found in the warmer sections of the country are reproduced as vegetative multipliers and not from seed.

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Promising Leads in Lily Breeding

By David Griffiths, *U. S. Department of Agriculture, Washington, D. C.*

LAST year the question of Hybridity in the Genus Lilium was discussed. This year the progress will be pointed out which has been made since the matter was discussed before.

Some hybrids of our West-American Martagons are proving decidedly vigorous and prolific in the hands of commercial growers. Kulshan, Shuksan, Douglas Ingram, Star of Oregon, and Sacajawea are proving amenable to culture and are among the most vigorous and prolific lilies.

The group of hybrids to which it is desired to call your attention especially is based largely on the Regal. Two of the varieties are well known. Sulphurgale as ordinarily seen today impresses one as a vigorous *Lilium regale*, but even after being grown from seed it is still more vigorous than the parents and shows its hybrid origin in that characteristic, if not in general form and appearance. George C. Creelman may also be looked upon as a glorified *L. regale,* but from what the author has seen of it from Professor Crow's clon it has other characteristics which make it desirable. Sulphurgale is a cross of *L. sulphureum* on *L. regale;* and George C. Creelman, one of *L. regale* on *L. sargentiae.* Lately *L. leucanthum* has been introduced into the complex, and blossoming plants in large colonies have been secured containing the blood of Sargent, Regale, Sulphureum, and Leucanthum in various combinations.

Besides these new lilies, which are the result of breeding, the growers on Vashon Island, who grow *Lilium regale* by the acre are segregating variants. Already there have appeared variants called white, red, and yellow, besides the ordinary Regals. The yellow is very close to the color of *L. sulphureum,* and seems to be meritorious.

Two of the lilies of the group, Sargent and Sulphureum, bear bulbils in the axils of their leaves like *Lilium tigrinum.* It is rather remarkable that the first two crosses in the aggregation, namely, Sulphurgale and George C. Creelman, although having one bulbil-producing parent, were both devoid of them. However, when *L. leucanthum* entered the hybrid complex, a number of bulbil-producing plants were obtained. They are not numerous, but enough of them have shown up to guarantee the use of this excellent method of propagation. Even pollen of George C. Creelman on *L. leucanthum* has given bulbils in a few cases.

As usual, the need is felt for more material of the lilies of this group from the native heath. It develops now that *Lilium regale* is much more widely spread and abundant in nature than we have been led to suppose. There probably are variants that would be valuable breeding material if indeed they may not be superior to the form we have. It is well known how exceedingly variable *L. leucanthum*

is. From the original collection by Doctor Henry from the canyons along the Yang-tse above Ichang, Doctor Baker described two lilies. A more recent collection in the same region by the Rev. Albert Cooper has yielded the same two lilies. This time there can be no question about their being the same species, for Mr. Cooper has informed the author that he sent to this country one pod of seed. *L. sulphureum* is quite variable, and few lily specialists are confident of the identity of the forms of *L. browni.* The Sargent lily seems to be quite constant, but there is only one collection of it thus far. What is needed is a thorough survey of the regions of China where these lilies are found native. It would not be surprising if intergrading hybrid forms may not be found between some of them.

In 1932 three sizable progenies of hybrid seedlings came into abundant blossom the third year from seed. They were derived, respectively, from *Lilium regale, L. sargentiae,* and George C. Creelman on *L. leucanthum.* There was a general similarity in all of the progenies. That derived from Creelman had the lightest colored flowers and that from *L. sargentiae* the darkest. All progenies were much more uniform than *L. leucanthum* itself, and in all cases the hybrids were much more robust than any of the parents. The increased vigor of these hybrids is very pronounced even in the seedling stage the first year. In 1931 a considerable colony of seed of *L. leucanthum* was planted and beside it a half dozen lots of its hybrids. In all cases the hybrids are distinguishable by their greatly increased stature.

For a number of years an effort has been made, but without success, to transmit the wonderful constitution of *Lilium henryi* to some other lily. It has failed to set seed for the past 3 years with pollen of any of the American turk's-caps. The past season, however, it accepted the pollen of three Asiatic species of Martagons. This is considered important. It has been endeavored to get the constitution of *L. henryi* engrafted on some other lily. *L. henryi* is not only one of the most robust of lilies but it is also one of the most resistant to the lily growers' worst enemies—mottling and botrytis.

Artificial Propagation of the Lily

By David Griffiths, *U. S. Department of Agriculture, Washington, D. C.*

DEPENDENCE is placed in the lily on seed, scale, stem, and bulbil propagations. Few genera are adapted to such a wide range of methods for the increase of stocks. Heretofore, scale propagation has been conducted, mostly under out-of-door conditions, which has worked well with a number of varieties, poorly with some, and ineffectively with others. It will be recalled that in the publications of the United States Department of Agriculture it is recorded that scaling and planting of the scales have taken place in midsummer to early autumn. At the Bellingham Bulb Station on Puget Sound it has been thought desirable to propagate by this method as early as possible so that the scales are able to form bulblets, and root before the autumn rains which introduce an unfavorable condition for development.

The Regal is one of the lilies that has not proved uniformly successful in scale propagation. The same may be said of Henryi and Speciosum, largely because they blossom too late at Bellingham. At the present time a scale method of handling is not necessary with the Regal or Henryi, but it might be with Speciosum, and the time is close at hand when desirable varieties of the Regal lily will appear. Their propagation will have to be on a vegetative basis, hence, the prospective importance of all the information possible on a scale method of handling even in this species, for which at the moment there is no urgent need.

During the spring of 1932 an artificial propagation was conducted with scales of 11 lilies. The bulbs were dug from the field at Bellingham on March 25 and 26, the scales removed, and placed thinly in trays and held in the bulb house until March 28 while an incubating chamber was prepared. The house at this time varied from 45 to 54 degrees F.

The incubating chamber was a small, well-insulated room in the basement of the bulb house. In it was installed a thermostatically-controlled electric heater and a humidifier. The operation of the chamber was very simple, as every detail except the ventilation was automatic. As the quantity of material was small, airing out once a day was ample.

The initial temperature after the introduction of the scales was 70 degrees F, but within three days this was adjusted upward to 79 degrees for the remainder of the period. The humidifier was operated so that the sides and ceiling of the chamber were constantly wet. There was drip from the ceiling at all times. The hygrographic record was quite constantly a little above 90 per cent.

The scales were placed in flats on the surface of dry sand. It is not considered now that this arrangement has any significance.

The next experiment will be conducted with the scales held on ¼-inch wire screens. It will be advisable to use an atomizer rather freely on scales of some varieties which are inclined to wilt too much even in such high humidity.

As already stated, the incubation began on March 28. The varieties used in the experiment with the date on which the first evidence of bulblet production was noticeable are as follows:

L. candidum and *L. testaceum,* April 9; *L. umbellatum,* April 13; *L. regale,* April 16; *L. martagon album,* April 17; *L. elegans, L. henryi, L. speciosum rubrum, L. thunbergianum, L. willmottiae,* and *L. No. 1370,* April 18.

No. 1370 is an unnamed seedling, closely resembling Shuksan. The scales of this variety, Elegans, and Willmottiae wilted rather more than the others. It was found necessary to spray them with a fine rose spray rather frequently until they and the surface of the sand were thoroughly moistened.

As will be noted, *Lilium candidum* and *L. testaceum* had started to produce bulblets in less than 2 weeks and by the end of the third week every variety was showing action. The propagation was continued to May 10 when the stocks were planted in the field.

By the middle of July, *Lilium candidum* and *L. regale* were farther advanced in top growth than any of the others. The growth on *L. umbellatum, L. speciosum rubrum, L. elegans,* and *L. thunbergianum* was uniform but thin, with an abundance of fine bulblets in the soil, which had not yet started top growth. *L. testaceum, L. henryi, L. martagon album,* and No. 1370 (*L. pardalinum* x *L. humboldti*) showed no top growth, but the bulblets were in good condition. *L. willmottiae* seemed to be rotting.

There is no question about the utility of this method of increasing stocks of many lilies. It seems particularly applicable to *Lilium regale* and *L. speciosum,*—a very fortunate thing because depending on three to six bulblets on the stems of *L. speciosum* is not entirely satisfactory, and propagation from scales in the open has not been uniformly successful with either species.

Another important advantage of this incubation of the scales becomes apparent when considering the relation of the incubated progeny to the season. It has been realized for a long time that much loss occurs in field scale propagation the first winter. The bulblets are small, shallow, and suffer from both excessive cold and moisture. With this artificial method of development they have a full season's growth before being subjected to the winter season. In other words, the latter part of the dormant season is used for propagation, thus keeping them out of the influence of the elements and gaining a season in time.

From the statement of the results of this experiment in the spring of 1932 it will be realized that the timing of the work was not entirely satisfactory; but the correct procedure seems to be quite clearly indicated from the results obtained. It is the opinion

now that the best time to start such a propagation of scales is the first of February. The incubation should continue until the middle of April or the first of May, or until the substance of the old scales is pretty well used up. At this time vigorous root action is quite certain to take place, which is another indication of the arrival of the time when the scales should be moved outside. If the old scales are well exhausted, the bulblets will form roots and top growth promptly when placed in soil. The process is precisely the same as the incubation of scooped hyacinths, and the reaction is the same. If the hyacinth propagation is late and the bulbs planted out while there is a great deal of substance left in the scales, no top growth may be made the first year. When carried far enough to exhaust the old scales there occurs a luxuriant growth of leaves in the spring.

Flower Production of Roses on Limed and Acidified Soils

By F. F. Weinard, and S. W. Decker, *University of Illinois, Urbana, Ill.*

A SERIES of greenhouse plots were laid out in the summer of 1931 to test the effects of acid and limed soils for roses.

An effort was made to approximate the extremes of reaction found in commercial ranges, pH 5.0 and 7.5. The acid plots received an initial application of 15 pounds of aluminum sulfate per 100 square feet, in July. Subsequent applications of 5 pounds each were made on October 20, December 16, and January 14. About a pound of sulfur per 100 square feet was scratched into the soil on May 6. The limed plots received 8 pounds of hydrated lime per 100 square feet in July, 2 pounds on October 20, and the same amount on December 16.

There were no significant differences noticed in the growth and flower production of the plants during the first season of the experiment. This year, however, many of the shoots on the limed plots, with Rose Hill especially, have leaves which are yellowed between the veins. There is very little of this chlorotic condition to be seen on the acid plots. The soils test pH 5.0 and 7.5.

In this experiment differences in soil reaction within ordinary limits had no effect on flower production. Growth and flowering of roses may apparently proceed normally and more or less independently of soil reaction where there is an abundance of available nutrients, but this may not be true for all soils. The yellowing of foliage which occurs on soils containing much lime is very likely an indication of a lack of soluble iron in the soil and plant.

Flower Development in Narcissus During Summer Storage

By D. Victor Lumsden,[1] *U. S. Department of Agriculture, Washington, D. C.*

THIS report deals with bulbs of *Narcissus pseudo-narcissus,* Linn., variety King Alfred, which were flowered at the Arlington Experiment Farm, Rosslyn, Virginia, during the spring of 1930 and stored in common storage in a bulb storage house during the summer.

Methods

On June 20, the bulbs were dug, the foliage removed, and the bulbs transported and placed one layer deep in wire mesh-bottomed trays in the bulb house. The trays were spaced in racks so that there was good air circulation.

From approximately 4 bushels of bulbs 100 so-called "round" bulbs were selected, with maximum horizontal dimensions between 45 and 50 mm, for this study. These bulbs were placed on a separate tray and rearranged each week so that the bulbs had essentially the same condition.

Temperature and humidity in the bulb house varied with the weather. They were conditions which at present are recognized as satisfactory for the commercial storage of spring flowering bulbs in the climate of Washington, D. C.

Sampling was started on July 22 and 10 lots of 8 bulbs each were taken at intervals during the storage season which terminated October 6. The bulbs were carefully cut to remove the scales until the developing bud was reached, which included diminutive leaves, and a flower which would have blossomed in 1931. In the early samples some of these leaves were left around the buds, but because of the size of the flower buds later in the season all of the new leaves were removed. The bulbs contained one primary bud and one or more secondary buds; only the primary bud of each bulb was used for this study.

The buds were killed and fixed in formalin acetic alcohol. They were later imbedded in 56 degree C paraffin, sectioned, and stained in Haidenhain's hemaetoxylin.

Observations

From the major growing point of the bulb is developed the primary flower bud while one or more lateral buds which may develop and ultimately produce flowers are often observed in the axils of the scales. A cross-section made through a mature bulb in the summer so that the flower is bisected will reveal the developing foliage and

[1]This work is being carried on in cooperation with Dr. David Griffiths, U. S. Department of Agriculture.

scale leaves which envelop the flower bud. Surrounding this bud, old scales can be seen still serving as storage organs which are 1, 2, 3, and sometimes 4-years old.

The development of a vegetative growing point through its period of scale and flower differentiation progresses as follows: in the spring at about the time the bulb flowers, or shortly thereafter, microscopic observations will reveal the origin of a new growing point at the base of the scape of the differentiating flower which will blossom 1 year later. In the fall at the time the bulbs are again planted this point will have developed so that two or three scales have split off from the center of the meristematic region. This development progresses as described while the bulbs are in storage during the summer. By the time of digging the following spring this growth region will have developed to the extent that five to seven scale leaves and three or four foliage leaves have been formed, and the flower for the next spring will have already started to differentiate, as will be described more in detail.

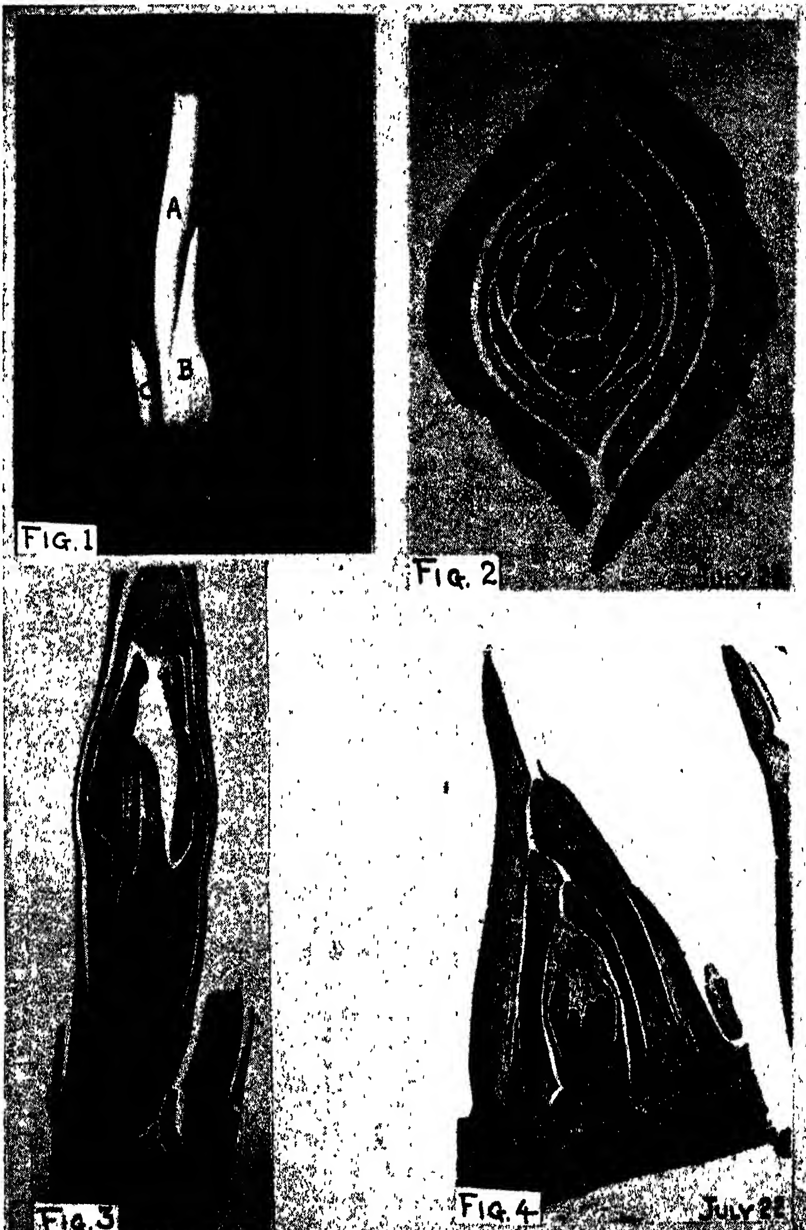
Fig. 1 shows the relationship of the base of the flower scape which bore a flower 1 year to the vegetative bud in which is enclosed the developing flower which will blossom 1 year later. This illustration shows the bulb with the scales removed as it appeared in September, 1930. *A* is the scape which bore a flower in the spring of 1930. *B* is a primary vegetative bud at the base and adjacent to scape *A*, which would have produced leaves and a flower in the spring of 1931. *C* is a lateral bud which was produced at the axil of scale. The dark tissue to which the buds are attached is the basal plate of the bulb.

Fig. 2 shows a cross-section taken from the first lot of buds, killed on July 22. This section was taken slightly below the tops of the developing anthers. In the center can be seen the three-carpelled pistil surrounded by the six stamens. Directly outside of this are the six perianth segments and finally the spathe of the flower bud. Outside the flower bud three leaves are included in the section.

Fig. 4 shows the appearance of a longi-section from a bud also killed July 22. The flower in the primary bud may be seen, and adjacent to this three developing leaves. Outside the leaves is one of the scales which completely envelops the leaves.

From Figs. 2 and 4 it can be seen that the development of the flower is well under way about 8 months before the time of anthesis.

Fig. 3 shows the appearance of a flower bud killed October 6, when bulbs are usually planted in the fall in the vicinity of Washington, D. C. It can be seen by comparison with Fig. 4, which is at the same magnification, that the various parts of the flower are now much advanced over the condition on July 22, and that additional differentiation and some elongation have taken place while the bulbs have been in storage during the summer. Two of the six stamens of the flower stand out boldly. The style of the flower projects up between



FIGS. 1–4. Flower development in narcissus during summer storage. (Explanation in the text.)

the two stamens, while directly below can be seen the ovules on the placenta within the ovary of the flower.

Referring again to Fig. 4, one can see at the base of the scape of the flower a growing point from which one scale is shown to have been already split off. This growing point would have split off scale leaves, foliage leaves, and a flower to blossom one year later than the differentiating flower above it. In Fig. 3 it can be seen that this growth region also develops during the summer, for this October section shows that two scales have split off and a third is just about to separate from the growing point. Here again some elongation can be noted.

Conclusions

The bulbs under consideration did not, as is commonly supposed, remain dormant during their period of storage in the summer. Significant changes went on during this period, and it is essential to know the most satisfactory conditions at which bulbs should be stored in order that they may develop and bloom in a satisfactory manner and at such a time as is desired. It is also of interest to know that any single mature unit of a narcissus bulb requires approximately 2 years from the time its first scales are differentiated until it flowers.

Growth of Gladiolus as Affected by Storage Conditions

By A. M. S. Pridham, and J. C. Ratsek, *Cornell University, Ithaca, N. Y.*

THIS subject has been dealt with in previous papers by Pridham and Thompson (3) and for California conditions by Emsweller (2). The recent recommendations of Dustan (1) and Weigel and Smith (4) for the control of the gladiolus thrips make the present topic timely and important.

The varieties used in these experiments were Albania, Alice Tiplady, Butterboy, Canarybird, Crimson Glow, Elizabeth Tabor, Lucette, Mrs. Frank Pendleton, Sheila, and White Butterfly. The majority of the data are based on the experiments with the variety Lucette.

The corms were harvested in the usual manner, October to November 15, dried, cleaned, sized, weighed, and placed in storage in small three-sectioned flats. The refrigerators used in these experiments varied somewhat in both temperature and relative humidity, but the average conditions expressed in degrees Fahrenheit and percentage humidity were, respectively, 32 degrees, 70 per cent; 40 degrees, 80 per cent; 50 degrees, 50 per cent; 60 degrees, 60 per cent; and 70 degrees, 30 per cent. To obtain data on the influence of humidity on the corms, two stone jars of 3-gallon capacity and covered with paraffin paper tops were placed in each refrigerator. One of two jars contained a quart of water over which the corms were suspended on a wire frame. In the second jar, the corms were suspended over 400 grams of calcium chloride.

The number of corms used in each sample varied according to the size of the corms. In the variety Lucette, there were four samples of 10 corms each of size 1.25 inches; and, for sizes 1.00 inch, .75-inch, and .50-inch there were 10 samples of 25 corms each. In other varieties the number of corms varied from 10 to 25 per sample, and the number of samples from one to four for each size of corm.

On April 15, the corms were removed from storage, weighed, examined for root and top growth, set in pots, and grown in the greenhouse for a month. After measuring the height of the plants and recording the number of corms which germinated, the plants were set in the field. The date of bloom and number of flower spikes produced were recorded and the plants dug October 1. After drying for a week the corms were cleaned, counted, and weighed.

These experiments were conducted both in 1931 and in 1932. In 1931, the flowering was interrupted by an infestation of the gladiolus thrips. In 1932, the planting was relatively free from these insects, especially the variety Lucette.

Without correcting the data of the temperature series for differences in humidity, and regarding only those differences between

TABLE I—EXPERIMENTS WITH THE VARIETY LUCETTE

Storage Temp. (Degrees F)	Corm Diameter (Inches) 1.25	1.00	0.75	0.50	0.25	High Hum. 1.25	Low Hum. 1.25
	Percentage Weight Loss by Corms in Storage (Nov.–April)						
30	14.82± 2.57	19.93± .44	23.45± .74	27.57± .67	30.44± 1.85	6.00	26.00
40	10.46± 0.61	14.84± .65	16.36± .36	18.84± .42	21.62± .92	5.00	27.00
50	18.67± 1.50	27.35± .32	28.08± .34	27.24± .65	27.88± .33	4.00	30.00
60	26.62± 0.37	25.10± .42	26.69± .52	26.39± .39	32.69± 1.31	13.90	33.33
70	38.63± 1.33	34.02± .66	28.27± .44	31 96± .90	36.18± 2.31	—	47.00
	Number of Days from Planting to Bloom						
30	115. 2± .57	113. 2± .30	112. 3± .31	113. 7± .31	119. 9± .62	114.0	118.7
40	112. 8± .89	110. 0± .20	110. 8± .18	111. 5± .12	115. 9± .67	108.2	113.1
50	111. 4± .68	107. 8± .33	109. 3± .53	111. 2± .40	118. 3± .87	105.7	109.8
60	108. 0± 1.09	113. 3± .72	116. 3± .40	116. 4± .02	120. 0± .53	112.7	107.5
70	108. 3± 1.95	101. 9± .57	101. 5± .49	111. 7± 1.1	120. 4± 4.77	82.2	107.5
	Number of Flower Spikes per Corm Planted						
30	1.80± .08	1.36± .12	0.95± .02	0.85± .03	0.68± .06	1.23	1.55
40	1.75± .20	0.95± .04	0.99± .01	0.93± .01	0.92± .06	1.13	1.05
50	1.38± .13	0.99± .03	0.96± .01	0.97± .01	0.83± .01	1.05	1.30
60	1.10± .01	1.03± .01	0.95± .01	0.94± .02	0.59± .02	0.98	1.13
70	1.13± .06	1.06± .03	0.83± .02	0.93± .01	0.92± .06	0.55	0.30
	Number of Corms Harvested per Corm Planted						
30	2.10± .11	1.481± .03	0.98± .03	0.88± .07	0.73± .07	1.40	1.72
40	1.80± .02	0.980± .04	1.02± .01	0.97± .01	0.97± .06	1.15	1.20
50	1.53± .13	1.104± .01	0.99± .01	0.96± .02	0.87± .05	1.05	1.37
60	1.38± .08	1.040± .01	0.99± .02	0.97± .01	0.66± .13	1.15	1.20
70	1.35± .10	1.286± .03	0.96± .01	0.81± .02	0.86± .05	0.70	0.75
	Yield of Corms as Percentage of Weight of Corms Planted						
30	156. 5±10.4	230. 1±15.4	278. 2±15.9	428. 3±16.0	694. 0±74.5	148.8	192.8
40	200. 0±18.5	197. 9±11.6	367. 6±11.6	534. 8±18.1	1066. 2±61.2	136.3	215.8
50	145. 5±10.6	200. 2± 3.0	307. 6±12.1	473. 1±10.3	967. 0±36.3	123.9	200.2
60	167. 5± 3.7	206. 9± 9.6	319. 1±16.9	472. 2±13.9	723. 5±40.2	154.9	210.0
70	183. 8±13.3	289. 6± 5.9	409. 6±13.1	642. 9±23.7	1289. 8±98.4	151.5	117.5

adjacent temperatures (smallest differences possible) as (30–40 degrees F), (40–50 degrees F), (50–60 degrees F), and (60–70 degrees F), the loss in weight during storage appears to be statistically significant in the majority of cases. The differences in number of days from planting to flowering are statistically significant except in the case of the largest corms and of the smallest ones. The number of flower spikes and the number of corms produced per corm planted are generally statistically significant, exceptions occurring for the largest corms in the first case, and for the ¾- and ½-inch corms in the second case. The differences in yield of corms expressed as percentage of the planted weight of corms are generally significant.

TABLE II—Correlation (r) Between Temperature and a, b, c, d, e Humidity Constant: (r) Between Humidity and a, b, c, d, and e Temperature Constant

	r Temperature		r Humidity		
	Low H.	High H.	30°F	50° F	70° F
a. Loss in weight in storage	+ 915	———	—.975	—.997	—.999
b. Days to bloom	+.908	+.890	—.999	—.348	—.251
c Number flower spikes/corm	+.816	+.899	—.432	—.753	—.017
d. Number corms produced/corm planted	+.840	+.873	—.151	—.120	—.338
e. Yield per cent weight corm planted	+.294	+.305	—.995	—.998	—.207

Considering only the 1- and ¼-inch corms the correlation between the temperature of the refrigerator and the loss in weight during storage, etc., the value of r (coefficient of correlation), is positive and high (Table II) and for the humidity of the refrigerator r (coefficient of correlation) is negative (Table II).

These data (Table II) suggest a relationship between the storage temperature and each of the plant responses under observation. The humidity of the storage chamber appears to be related only to the loss of weight of the corms during storage and not to the production of flower spikes or of corms.

The response of different sized corms of Lucette to storage conditions appeared to follow a general trend in the case of loss in weight in storage. Any one of the three larger sized corms may flower earliest depending on the storage conditions. The number of flower spikes and of corms produced, decreased as the diameter of the corm planted decreased. The yield of corms expressed as percentage of the planted weight of corms increases sharply as the diameter of the corm decreases.

The response of other varieties to the above storage conditions is similar to that of Lucette in some cases and different in others. The trend in the case of number of days to bloom is generally the same as that for Lucette. The number of flower spikes produced per corm varies in trend, generally the number is greater at 30 degrees than at 70 degrees. The weight yields of corms expressed as percentage of weight of corms planted follows approximately

this same trend; and is much greater in some varieties than in others, usually it is highest at 50 degrees, second highest at 70 degrees, and lowest at 30 degrees.

TABLE III—CORRELATION (r) OF THE RESPONSE OF LUCETTE (CORMS 1 INCH DIAMETER) WITH THAT OF OTHER VARIETIES

Variety	r Days to Bloom	r No. Spikes/Corm	r Yield Per cent Weight
Alice Tiplady	+.796	—.0045	—.531
Canary bird	+.878	+.0052	—.342
Sheila	+.988	+.0008	—.894
White Butterfly	+.964	+.0058	—.009

The number of corms produced per corm planted is the only plant response which was not greatly influenced by thrip injury; hence, the only reliable source of comparison between 1931 and 1932 results. The value of r for several varieties (corms 1-inch diameter) is: Albania + .630, Alice Tiplady + .928, Butterboy + .836, Canarybird + .622, and Lucette + .979.

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The Response of Some Ornamental Plants to Soil Reaction

By L. C. Chadwick and J. H. Gourley, *Experiment Station, Wooster, Ohio*

RECOMMENDATIONS in the literature (1, 2, 3, 5) concerning the optimum soil reaction for ornamental plants are variable and meager. This, in part, is due to the fact that these recommendations have been based mostly on observations. Too many times these observations have been limited to one locality. Plants respond differently to the same degree of acidity in soils of different texture and mineral salt content.

Preliminary experiments were conducted to ascertain the optimum reaction for the growth of *Iris germanica, Lupinus polyphyllus, Daphne cneorum, Lupinus hartwegi*, and *Delphinium ajacis*. All tests were conducted in the greenhouse but with varying reactions and soil types.

Rhizomes of the German iris variety, Alcazar, and one other which was not determined, were planted September 1, 1930, in plots adjusted at half-point intervals between pH 4.5 and 8.0. Each plot, 7x8 feet, was prepared with Canfield Silt Loam (pH 5.0) with which was incorporated a 1-inch layer of German peat (pH 3.5). The peat was added to increase the humus content and improve the general texture of the soil. Increments of aluminum sulphate or hydrated lime were added to the plots until the desired reaction was obtained. Bi-weekly tests, either by the LaMotte method or electrometrically, were made. Rhizomes of a uniform size were selected and three of each variety were planted in each plot. Identical care was given all plots except that various amounts of aluminum sulphate or hydrated lime were added to maintain the desired reaction. The data recorded July 22, 1932, are given in Table I.

TABLE I—Influence of Soil Reaction on the Growth of *Iris germanica* var. Alcazar, September 1, 1930, to July 22, 1932

Plot	Reaction (pH*)	Av. Weight of Three Plants (Gms)	Av. Number Shoots per Plant	Av. Height of Foliage (Ins.)	Length of Flower Stems June 15 (Ins.)	Condition of Foliage
1	4.49	276	4	9	3	Very pale, tip burn
2	4.86	316	4	11	5	Very pale, tip burn
3	5.46	385	6	13	8	Pale, tip burn
4	6.05	401	5	14	10	Pale, tip burn
5	6.48	393	5	15	10	Green
6	6.93	529	5	16	14	Dark green
7	7.56	561	4	18	16	Dark green
8	8.05	677	5	20	22	Very dark green

*The last reading before the iris plants were removed, recorded electrometrically with a quinhydrone electrode, June 21, 1932.

A similar test was conducted with *Lupinus hartwegi* and *Delphinium ajacis.* A bed 48 feet long was divided into eight 6-foot plots. The same soil was used as with the iris and the reactions adjusted in the same way. Seventy-two seeds, 1 inch apart, were sown in each plot November 1, 1931. The data taken from April 20 to May 5, 1932, are recorded in Table II.

TABLE II—INFLUENCE OF SOIL REACTION ON THE GERMINATION AND GROWTH OF SEEDS OF *Lupinus hartwegi* AND *Delphinium ajacis*
NOVEMBER 1, 1931 TO MAY 5, 1932

Plot	*Lupinus hartwegi*			*Delphinium ajacis*		
	Number Germinated	Number Grew	Av. Stem Length (Ins.)	Number Germinated	Number Grew	Av. Stem Length (Ins.)
1	0	0	0	0	0	0
2	14	10	14	11	7	26
3	53	44	23	37	31	34
4	57	43	24.5	30	33	30
5	59	44	25.2	65	59	48
6	58	49	27.5	68	66	48
7	60	50	26	69	66	44
8	62	49	26.5	69	66	43

Tests with *Daphne cneorum* and *Lupinus polyphyllus* were conducted under different conditions. A 50-foot greenhouse bench was divided into two sections of five plots each. Ten plants of each were planted in each plot. One section contained a good compost soil and the other a mixture of equal parts by volume of this compost soil and Michigan peat moss. The plots were adjusted at unit intervals from pH 4.0 to 8.0. Aluminum sulphate and hydrated lime were added to obtain the desired reaction. The reaction of the plots were tested by the LaMotte method or electrometrically every 3 to 4 days for the first three months, thereafter at weekly intervals. A total of 117 tests were made. Adjustments were made as required. Tests for nitrate nitrogen showed about 10 parts per million in the soil plots but slightly higher in the mixture of peat and soil. Phosphorus tests showed the presence of about 100 parts per million in both soil types. No fertilizers were added during the course of the experiment. The data recorded are presented in Table III.

DISCUSSION

The iris plant showed no appreciable differences until about January 1, 1931. At that time plots 6, 7, and 8 showed better foliage color and larger leaves. In plots 1 and 2 the growth was stunted and tip burning of the leaves was prevalent. Plots 3, 4 and 5 were increasingly better in the order given. During the following 18 months there was a gradual widening of the growth behavior between plots 1 and 8, those in the highly acid soil being practically worthless. The data in Table I show that, for the iris varieties in question and under

TABLE III—INFLUENCE OF SOIL REACTION ON THE GROWTH OF *Daphne cneorum* AND *Lupinus polyphyllus*

Plot	Reaction				Notes
	Average of 117 Tests (pH)	Variation 117 Tests			
		Low (pH)	High (pH)	Number of Tests at Desired pH	
			Soil		
1	4.17	3.8	4.6	64	Lupine—7 plants dead, other stunted, no root growth. Daphne—2 plants dead, others stunted, foliage tip burned, no root growth.
2	4.92	4.4	5.2	55	Lupine—Growth stunted, poor. Little root growth. Daphne—Growth weak and stunted. Little root growth.
3	6.10	5.4	6.4	23	Lupine—Top and root growth fair, pale green foliage. Daphne—Top and root growth fair, nearly normal color.
4	6.98	6.8	7.4	68	Lupine—Top and root growth vigorous. Best of the soil plots. First plot to show bloom in soil. Daphne—Vigorous top and root growth. Normal color.
5	8.12	7.6	8.6	22	Lupine—Top and root growth vigorous. Daphne—Top and root growth very good. Best of soil plots. Order of bloom: plots 5-2-3-4-1.
			Peat and Soil		
1	4.10	3.8	5.0	61	Lupine—4 plants dead, others stunted. No root growth. Daphne—Growth stunted and weak, slightly better than plot 1—Soil.
2	5.03	4.8	5.8	74	Lupine—Same as plot 2—Soil. Daphne—Same as plot 2—Soil.
3	5.91	5.2	6.4	33	Lupine—Top and root growth good. Normal color. Daphne—Growth slightly better than plot 3—Soil.
4	6.88	6.4	7.2	42	Lupine—Best of all Lupine plots. Top and root growth very vigorous and healthy. First plot to bloom. Daphne—Vigorous top and root growth.
5	8.11	7.4	8.6	31	Lupine—Top and root growth very good. Daphne—Best of all plots. Order of bloom plots 5-4-3-2-1.

the conditions of this experiment, a neutral or alkaline soil is desirable.

Lupinus hartwegi germinated and gave good growth in plots 3 to 8 inclusive. Those in which the reaction was neutral or alkaline gave somewhat the best germination and stem length. None of the seeds germinated in plot 1 (pH 4.5). *Delphinium ajacis* seed failed to germinate in plot 1 and gave very poor germination and growth in plot 2. Plots 3 and 4 gave only about 50 per cent germination but satisfactory stem growth. Plots 5, 6, 7 and 8 gave very good germination and growth. The stem length was slightly superior in plots 5 and 6 (pH 6.5 and 7) but germination was slightly lower. These tests show that for the conditions under which they were conducted a neutral or alkaline soil reaction may be considered best for their growth.

With *Daphne cneorum*, in both the soil and the soil and peat sections, by far the best growth occurred in plots 4 and 5 (pH 7 and 8). The two alkaline plots (plot 5) were slightly the best and were the first to bloom. The other plots were increasingly poorer in the order 3, 2 and 1. The plants in plots 1 and 2 made very little top or root growth. The growth of *Lupinus polyphyllus* in the different plots was much the same. Plot 4 gave the best results followed closely by plot 5. The others showed poorer results in the order 3, 2 and 1. Tests for active aluminum in plot 1 showed amounts as high as 80 parts per million. Since soils showing more than 10 parts per million are apt to produce very poor results except with distinctly acid tolerant plants (4) it is highly probable that much of the injury resulting in plots 1 and 2 was due to toxic active aluminum rather than the high concentration of hydrogen ions. Soils containing large amounts of phosphorus in an available form tend to counteract aluminum toxicity in that the aluminum is precipitated from the soil solution.

The conclusions that can be drawn from these preliminary tests are that both plants make excellent growth in neutral or alkaline soils. A liberal incorporation of peat moss with the soil aids the growth of both plants. When different chemicals are used to adjust the soil reaction it is probable that the acid reactions will not be as toxic.

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Bank Sand as a Medium in Which to Grow Chrysanthemums

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CONNORS (1, 2), Laurie (3), and others have already demonstrated that various crops can be successfully cultivated in sand to which either nutrient solutions or salts are added. The sand used in the following experiment was commercial "washed sand" of pH 7.

The chrysanthemum, Gold Lode, was propagated March 15, potted (in sand) April 1 in 2-inch pots, set 6 x 8 inches June 1, in 24 separate plots of greenhouse bench. Two plots contained soil and two a mixture of bank sand and German peat, 4:1 by volume. The remainder contained only bank sand, and each was separated by a 6-inch space from its neighboring plot.

Nutrients were added on the unit basis of 0.4 gram calcium nitrate, 0.2 gram ammonium sulphate, 0.2 gram of potassium sulphate, and a trace of iron chloride per plant per week. The nutrients were applied in solid form using quartz sand as a filler to ensure even distribution.

On August 17 applications of nitrogenous salts were discontinued from half of the plots, but on September 1 were again applied in varying amounts, namely, 0, 25, 50, 75, and 100 per cent of that previously applied, at the same time the second series of plots received additional potassium and phosphorus at similar rates.

The general color of the foliage and the habit of growth of each plant was recorded; also the date on which the flower buds showed color, started to open, and the date when in full bloom. Record was also made of the diameter of the flower and length of the stem. A composite sample of the plot (four to six leaves per plant) was taken for analysis of total nitrogen by the official Kjeldahl method modified to include nitrate.

The foliage of plants which received nitrogen continually was deep, medium, glossy green, of good size, the lower leaves remaining in good condition through anthesis. The foliage of plants from which nitrogen was withheld showed young leaves that were small and light bluish-green, and mature leaves that were light green with a yellow cast and occasional red veining. The petioles formed an acute angle with the stem thus holding the leaves in a nearly horizontal position. As a group the plants were somewhat open in appearance.

While there was a rather clear and consistent difference between the plants of the two series, there was no marked difference between the plants of the several plots of each series. Table I gives the date of bloom, length of stem, and diameter of bloom for the plots of the two series.

TABLE I—COMPARISON OF DISCONTINUOUS AND CONTINUOUS NITROGEN

Fraction N or PK Sept. 1 to Nov. 1	Number of Plants	Date Bloom (October)		Stem Length (Inches)		Flower Diameter
		Mean	PEm	Mean	PEm	
		Discontinuous Nitrogen Series				
0..........	27	5.3[1]	±0.3	21.3	±0.9	4.7±0.3
	29	11.4	±0.4	29.9	±0.8	4.4±0.6
¼.........	27	7.9	±0.2	31.7	±0.9	4.4±0.6
	25	6.8	±0.3	27.1	±0.6	4.7±0.3
½.	24	5.2	±0.4	25.9	±0.4	4.9±0.1
	25	9.6	±0.3	29.5	±0.5	4.5±0.4
¾.........	28	6.9	±0.3	23.4	±0.7	4.5±0.5
	30	11.9	±0.3	30.0	±0.6	4.4±0.6
1..........	29	5.1	±0.3	23.4	±0.6	4.8±0.6
	26	11.8	±0.3	31.9	±0.8	4.4±0.6
Soil check .	29	6.1	±0.7	34.3	±0.4	4.7±0.4
Peat check..	23	6.7	±0.3	28.2	±0.5	4.8±0.1
		Continuous Nitrogen Series				
0.	26	16.3	±0.5	28.5	±0.9	4.0±0.0
	25	8.9	±0.3	24.6	±0.6	4.2±0.6
¼	27	14.2	±0.4	27.5	±0.5	4.1±0.3
	16	9.3	±0.4	25.1	±0.1	4.2±0.8
½. . ..	25	12.2	±0.5	29.4	±0.6	4.7±0.7
	28	8.1	±0.3	26.8	±0.6	4.4±0.6
¾... ...	24	15.1	±0.5	27.9	±0.5	4.2±0.4
	25	9.6	±0.4	23.3	±0.6	4.3±0.7
1..	24	14.1	±0.3	29.6	±0.6	4.3±0.6
	19	8.8	±0.5	25.9	±0.6	4.3±0.8
Soil check	24	14.8	±0.1	35.1	±0.9	4.8±0.3
Peat check..	25	9.3	±0.2	28.7	±0.5	4.2±0.6

[1]Data calculated to four decimal places and condensed to one.

Analysis of the data for the plots of either series fail to indicate significant differences between neighboring plots except in isolated cases. If adjacent pairs of plots, one from each series are compared with reference to the position in the greenhouse, two series of significant differences are obtained. The differences in date of bloom decreases in order of magnitude in one section of the house as the plots are compared proceeding from east to west, and in the second instance from west to east. For height of plant the one series of differences follows the same magnitude direction course while the second passes through a maximum; this is true also for the difference in diameter of bloom and holds for both series. These variations in the magnitude of the difference between adjacent pairs of plots account for the fact that when the two series of plots are compared as such by Student's method, no significant difference can be found between them.

On a dry weight basis the composite leaf samples taken from each plot contained 2.19 per cent total nitrogen in leaves of the plants receiving nitrogen throughout the season, and 1.28 per cent in the plots from which nitrogen applications were discontinued August 17 to September 1. The difference in growth between ad-

jacent plots of the same series show no significant correlation with the difference in the amount of nitrogen added to the plots. Leaves within a plot selected for green color as opposed to yellow were found to contain 1.34 and 1.93 per cent nitrogen as opposed to 1.25 and 1.67. There is a significant though negative correlation ($-.692 \pm .0809$) between the date of bloom and the total nitrogen as determined in composite samples from the plots, a much weaker ($r = -.064 \pm .140$ for length of stem and $r = -.279 \pm .117$ for diameter of bloom) correlation exists for the other characters under consideration.

A similar set of experiments to the above were conducted in pure quartz sand. The plants were grown in glazed 3-gallon jars without drainage. The mid-season omission of nitrogen from the nutrients added did not produce marked differences in foliage color for that of all plots was of a deep, glossy green.

The experiments suggest that while the chrysanthemum, Gold Lode, can be grown satisfactorily for commercial purposes in bank sand, that deleting nitrogen from the fertilizing elements brings about a marked change in the growth of the plant; this change is not easily reversed when it occurs just prior to anthesis. The use of greenhouse benches in which drainage is possible tends to increase the irregularities brought about by the omission of nitrogen from the nutritional program.

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Further Studies of the Growth of Ornamental Plants in Quartz Sand

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IN 1929, 1930, 1931 a number of tests were started at Ohio State University, using washed sand, containing 2 per cent organic matter, in place of composted soil. In place of using nutrient solutions, the chemicals were applied in dry form to approximate as closely as possible the present commercial practices. When transplanted into benches or in pots the soil was washed from the roots of the plants to eliminate any additions of organic matter as well as the influence of the nutrients contained in the soil. In addition a series of tests were run with Snapdragon and Calendula from roots of which soil was not washed. There was not any difference in the ultimate results secured. The small amount of soil (2½-inch pots) had no advantage over the washed roots. In general, the results of these tests showed that the application of nutrients to plants grown in sand produced crops which were fully as satisfactory as those grown in soil (1).

Further studies with plants grown in sand were continued at the greenhouses of the Department of Horticulture, Ohio State University, to determine the possibilities of the use of sand as a growing medium in place of soil. The possible advantages lie in the direction of elimination of yearly replacement of media, the facilitation of more accurate and specific recommendations for additions of nutrients, the reduction of troubles arising from problems of aeration and moisture, the elimination of soluble salts accumulations, and the ease of sterilization.

TABLE I—APPLICATION OF NUTRIENTS TO CHRYSANTHEMUMS

Treatment	Frequency of Applications (Days)	Stem Length (Inches)	Diameter Flower (Inches)
1–4–1 (at rate of 2 lbs. to 100 sq. ft. per application)	7	59	5
	14	59	5
	21	59	5
	28	48	5
	35	42	4.25
	42	40	4

Instead of using chemically pure nutrient solutions, commercial mixtures were applied in varying ratios in dry form to such bench crops as chrysanthemums, snapdragons, stocks, calendulas, and others. The rates of applications varied with materials depending upon their nutrient content. The most satisfactory ratio for most crops tried proved to be 1–4–1 applied at the rate of 2 pounds to 100 square feet of bench per application. The material used was composed of ammonium sulphate, superphosphate, and potassium chloride.

A series of tests was run to determine the optimum frequency of application of fertilizers to chrysanthemums. Table I indicates the results.

These data show that a sudden drop in stem length and diameter of flower occurs when intervals longer than 28 days elapse between applications. It is also quite apparent that more frequent applications at the rate indicated are not necessary. During the life of the crop four applications are all that are needed when used at 28-day intervals. This involves the use of 8 pounds of fertilizer for the season for every 100 square feet at a cost of 20 cents, or about 1/3 of one cent per flowering stem, when grown to two stems to the plant. The plots to which nutrients were applied at 35 and 42 days showed definite symptoms of nitrogen and phosphorus deficiency. Further work is being continued at the present time with amounts and frequencies of application.

Doubling of Stocks

Previous work by the writer has indicated that abundance of available nitrogen was responsible for the greater percentage of doubling in stocks. To verify this in sand cultures, a series of tests was run using a number of varying ratios.

TABLE II—Comparative Average Percentage of Doubles and Singles (Variety Lilac Lavender)

Treatment	Per cent Singles	Per cent Doubles
Check—compost	45.0	55.0
Compost and nitrogen	27.8	72.2
One-half sand and one-half peat	44.5	55.5
One-half sand and one-half peat and nitrogen	18.0	82.0
Sand and nitrogen	17.4	82.6

Data show that nutrients of nitrogenous nature are responsible for larger percentage of doubling in stocks. Nitrogen was applied bi-weekly in the form of liquid urea, dissolved at the rate of 1 ounce to 7 gallons of water.

Carnations

To indicate the possibilities in the use of sand in commercial practice the following table shows the comparison between soil,

TABLE III—Composite Results of Several Tests

Treatment	Average Number Flowers per Plant	Average Stem Length (Inches)	Average Diameter (Inches)	Number Flowers per square Foot per Year
Check—compost	7.5	18.7	2.3	21
One-half sand and one-half peat	8.4	18.3	2.4	22.3
Sand	8.1	18.7	2.3	21.2

sand and peat, and sand to which nutrients in the ratio of 1–4–1 were added bi-weekly at the rate of 2 pounds to 100 square feet. In all, 12 applications were made during the season, since only two additions were made in December and January.

Pot Plants

Although of no practical importance, several kinds of flowering plants were grown in sand cultures to determine the most satisfactory ratios, amounts, and periods of application. The results were variable for different crops but in general, standard application of fertilizers containing available N, P, and K produced satisfactory plants and in many instances these were superior to those grown in good greenhouse compost soil.

Conclusions

Conclusions from tests conducted during the past 3 years are:

1. Good quality roses, chrysanthemums, snapdragons, stocks, carnations, and calendulas can be grown in either pure sand or ½ sand and ½ peat to which nutrients composed of N, P, and K from commercial carriers, in dry form, are added regularly.
2. Low ratio nutrients (1–4–1) composed of ammonium sulphate, superphosphate, and potassium chloride applied to plants at 2- to 4-week intervals, depending upon season of the year, and at approximate rate of 2 pounds to 100 square feet are sufficient to produce plants comparable in quality to those grown in good soil.
3. Sand plots require more water than soil only during the summer months.
4. Pot plants such as cineraria, fuchsia, calceolaria, hydrangea, calla lily, various spring bulbs, can be grown to excellent size and quality in sand to which nutrients are added regularly.
5. Hydrangeas and fuchsias responded best when aluminum sulphate was added to the sand to bring the reaction to pH 5.
6. Sand is so much heavier than soil that it is not a suitable medium for growing plants in pots, making the pots too cumbersome to handle.
7. The shifting of pot plants growing in sand to pots of larger sizes is more difficult than shifting soil-grown plants because the sand is not as cohesive as soil.
8. Certain economies are effected by the use of sand. Yearly changing of soil in benches is eliminated. Variations in structure and nutrient content of composted soils are avoided, which will lead to more standardized practices in nutrition. The problems of aeration and moisture in the soils are reduced to a minimum. Sterilization is simplified and accumulation of soluble salts prevented.

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Further Studies of Photoperiodism of the Chrysanthemum

By G. H. Poesch, *Ohio State University, Columbus, O.*

KNOWING that early pompon and standard chrysanthemums have a moderate market demand, further trials of effects of the length of short-day treatment and succession of cropping have been made. The method of shortening the photoperiod has been described (1, 2). The black cloth (68 x 104 threads per square inch) was applied at 5 P. M. and removed at 7 A. M.

All plants were planted May 19, from 2½-inch pots. One group of pompons was planted 9 x 9 inches while all others were set at a distance of 8 x 8. Standards were grown two stems per plant. Pompons were pinched twice; once before planting and again one week later. Disbudded varieties were grown three to five stems per plant. The soil was fertilized with an application of superphosphate, 8 pounds per 100 square feet before planting, and two applications of ammonium sulphate were made during the remainder of the season.

Period of Short-day Treatment

To determine the exact date to discontinue short-day treatment for the proper formation of a flower, 100 Silver Sheen and 50 White Wings were grown in 6-inch pots. The shortening of the day was started July 15. Two pots of Silver Sheen and one of White Wings were removed each day and placed in a normal daylight condition. This was carried on for 47 days.

The results showed that both standard and pompon varieties have an optimum time to produce early bloom. Silver Sheen produced good-sized flowers when the short-day treatment was continued for 24 days, whereas with White Wings the best results were obtained when this treatment was carried on for 30 days. Plots subjected to the short photoperiod for 47 days were not injured from this prolonged short-day treatment. The plots receiving 1 to 7 days of short photoperiod formed their buds at the same time as the check. The plants that received 8 to 21 days of short-day treatment, in case of Silver Sheen, and 8 to 24 days, in case of White Wings, formed buds very similar to "crown buds." This type of bud did not develop properly, giving poorly shaped and late blooming flowers. These plots flowered several days after the plot receiving seasonal light conditions. In the case of White Wings, irregularity in the time of flowering developed when the plants were given 8 to 24 days of short-day treatment, but when this time was extended to 30 days, normally developed flowers were obtained.

Five plots of 126 plants each of pompon variety White Wings were given a short photoperiod for a varying number of days.

The black sateen cover was applied on July 15 in the manner already indicated and was applied for 14, 21, 28, and 35 days, with one plot receiving no short-day treatment.

TABLE I—RESULTS OF THE PERIOD OF SHORT-DAY TREATMENT ON WHITE WINGS

Plot No.	Period Short-day Treatment	First Appearance of Bud	Date Bud Showed Color	Date of First Cutting	Date of Last Cutting	Average Stem Length (Ins.)	Diff. in Flowering (Days)
1	Normal Treatment	Sept. 7	Oct. 5	Oct. 13	Oct. 20	44	
2	14 days	Aug. 4	Sept. 27	Oct. 4	Oct. 20	32	9
3	21 days	Aug. 4	Aug. 30	Sept. 16	Oct. 20	29	27
4	28 days	Aug. 4	Aug. 30	Sept. 12	Oct. 11	30	31
5	35 days	Aug. 4	Aug. 30	Sept. 12	Sept. 23	30	31

In the above table it will be observed that plot 5 was the only plot which flowered uniformly. Plots 2, 3, and 4 flowered very irregularly; the time of cutting the crop varied from 16 to 34 days, which commercially would be very unsatisfactory. The reason for this uneven flowering is attributed to the fact that the short-day treatment was discontinued too soon. Another type of bud, other than the terminal is formed when the treatment is not continued for at least 30 days.

The plot which received 35 days of reduced photoperiod produced a very uniform cut, and the entire crop was harvested within 11 days after the first cutting as compared with 7 days in the check plot. However, there was a difference of 31 days in earliness in favor of the plot receiving 35 days of reduced day length from July 15 to August 19. Flowers in plot 4 were cut 31 days in advance of the check plot, but the crop lasted until the check plot was cut.

TABLE II—RESULTS OF THE PERIOD OF SHORT-DAY TREATMENT ON INDIANOLA

Plot No.	Period Short-day Treatment	Date of Taking Bud	Date Bud Showed Color	Date of Cutting	Av. Stem Length (Ins.)	Av. Flower Diameter (Ins.)	Diff. in Flowering (Days)
1	Normal Treatment	Sept. 8	Oct. 3	Oct. 17	45	6.0	
2	14 days	Aug. 10	Sept. 7	Sept. 18	39.5	6.0	29
3	21 days	Aug. 10	Aug. 22	Sept. 7	34	5.75	40
4	28 days	Aug. 10	Aug. 20	Sept. 2	34	5.75	45
5	35 days	Aug. 10	Aug. 22	Sept. 2	34	5.75	45

This same treatment of shortening the photoperiod was carried out with the following standard varieties, namely, Indianola, Calumet, Detroit News, and October Rose. In addition, shading the glass to reduce fading of the flowers was tried on all varieties.

Here again the plots which were given short-days for a period of 14 or 21 days flowered very irregularly. The buds on the plants in plot 2 acted very similarly to "crown buds." The entire plot did

not flower at one time and a large number of culls resulted. No apparent difference was noted between plots 4 and 5. The buds were beginning to break at the time the short-day treatment was discontinued on plot 5. The stem length was greater under normal treatment. This latter should be expected and for that reason the plants that are to be grown under short-day conditions should be planted earlier.

October Rose, Detroit News and Calumet responded very similarly to Indianola.

Decreasing the light intensity by shading the glass with whitewash did not stop the fading of the bronzes and the pinks entirely, but was helpful. Detroit News did not fade as much as Calumet or Indianola.

Succession of Cropping

The value of having a succession of bloom from the first of September until the 15th of October is very important. For that reason the photoperiod should be governed to have the crops following one another. Eleven varieties of pompons were planted 9 x 9 inches with 14 plants of each variety, or 154 plants, composing a plot. Plots were given a reduced photoperiod starting July 15, 22, 29, and August 5. Each plot was treated from 38 to 40 days, and at the end of these periods the buds were showing color.

TABLE III—Period of Short-Day Treatment of Pompon Variety Cora Peck Buhl

Plot No.	Period Short-day Treatment	First Appearance of Bud	Date Bud Showed Color	Date of Cutting	Av. Stem Length (Ins.)	Diff. in Flowering (Days)
1	July 15–Aug. 22	Aug. 1	Aug. 27	Sept. 8	24	39
2	July 22–Aug. 31	Aug. 10	Sept. 2	Sept. 12	26	35
3	July 29–Sept. 7	Aug. 16	Sept. 7	Sept. 16	28	31
4	Aug. 5–Sept. 12	Aug. 22	Sept. 12	Sept. 18	28	29
5	Normal Treatment	Sept. 7	Oct. 9	Oct. 17	47	

The results show that successfully manipulating the time of applying the short-day treatment will result in different times of flowering. One variety may be grown and flowered over a long period of time by manipulating the time of starting the short-day treatment. The plants flowered very uniformly in all plots. The stem-length was longer when the treatment was applied later in the season. The other varieties grown in this experiment are as follows: White Wings, Iridescent, Pink Dot, Ermalinda, Rodell, Irene, Ethel, Varsity, Firebird, and Gold Lode. All varieties flowered very satisfactorily. Varieties such as Rodell and Irene flowered the early part of September in plot 1 and in all plots were entirely cut out within five days of the start.

Succession of cropping has an advantage in that one good variety may be subjected to short-day treatment at weekly intervals until

August 15, and in that way only a few varieties need be grown. This succession may be manipulated with standards as well as with pompons.

Varietal Behavior

Everyone is interested in knowing what varieties will flower the best under this new method of culture. The following table contains varieties of pompons and standards that have been tried and have proved their worth.

Pompons: Capt. Cook, Cora Peck Buhl, Ermalinda, Ethel, Firebird, Greta, Irene, Iridescent, Jewell, Leilah, Lilac, Minong, Nubian, Nuggets, Pink Dot, Rodell, Uvalda, Varsity, and White Wings.

Standards: Ambassador, Betsy Ross, Celestra, Chieftain, Detroit News, Friendly Rival, Golden Bronze, Hilda Bergen, Honeydew, Indianola, LaFrance, Mefo, Mrs. H. E. Kidder, Muskoko, Pink Chieftain, Richmond, Rose Glory, Silver Sheen, and Sunglow.

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1. Laurie, Alex. Photoperiodism, practical application to greenhouse culture. Proc. Am. Soc. Hort. Sci. 27: 319. 1930.
2. Poesch, G. H. Studies of photoperiodism of the chrysanthemum. Proc Amer. Soc. Hort. Sci. 28: 389. 1931.

The Effect of a Deficiency of Nitrogen, Phosphorus, and Potassium Upon the Growth of Chrysanthemums

By J. Hapgood Brooks, 3rd, *Cornell University, Ithaca, N. Y.*

Abstract

THE results are inconclusive because of the small number of plants used in each culture, so that the deficiency symptoms as noted are merely indications. A lack of nitrogen may be shown by a slight yellowing of the margins of the leaves which later turn yellowish-green. The upper and younger leaves become stiff and point upward from the stem while the lower leaves hang close to the stem. When nitrogen is lacking, the size of the flowers is reduced and the time of flowering is retarded.

No phosphorus deficiency symptoms were noted in the experiment, but this seems due to the fact that a large amount of phosphorus, possibly in excess of the amount needed by the plants, was adsorbed by the sand.

A lack of potassium may be shown by a yellowing of the tips of the lobes of the leaves. The yellowing spreads toward the base of the leaf which may later turn brown and die.

No great differences were found in the average length of stem and the average dry weight of tops and roots of the plants in any of the cultures. These results are thought to be due to the fact that buds were taken September 12, which was approximately 10 days after the respective nutrient salts were removed from the culture solutions. After the appearance of the buds, utilization of nutrients may have been limited mainly to flower development.

A Study of the Utilization of Land for Vegetable Growing in New York State

By F. O. Underwood, *Cornell University, Ithaca, N. Y.*

Abstract

This material will be published elsewhere.

Further Results With Black Cloth for the Production of Early Blooms of the Chrysanthemum

By Kenneth Post, *Cornell University, Ithaca, N. Y.*

MANY papers concerning effects of short-day treatment of chrysanthemums have recently appeared (2, 3, 4). This paper presents data showing the effect of (1) various types of black cloth, (2) darkening a few nights and not until color was showing in the buds of pompon varieties, (3) the time of propagation, and (4) the time of the last pinch.

Methods

Unless otherwise noted the plants were grown according to standard commercial greenhouse practice. They were selected for uniformity at the time of benching and were planted at a distance of 7½ x 9 inches. All were planted from 3-inch pots with the exception of the April propagated ones which were in 2-inch pots at that time. Standard varieties were grown two stems to a plant and pompon varieties were pinched regularly as soon as five joints were developed. The practice of pinching on pompons was continued until the dates specified in the various experiments.

Black sateen cloth of the weave 68 x 104 threads to the inch was used unless otherwise specified. The plants were completely enclosed with this material at 6 P. M., and it was removed at 7 A. M. This method of shortening of day was similar to that previously reported 1931 Proceedings. Unless otherwise noted all darkening treatment was continued until color was showing in pompon varieties and until the buds of all plants in the test were taken on standard varieties. Blooms were cut when the center petals were unfolded. Pompons were cut when the first bloom on the stem was fully developed. All buds, which were showing color, when the stems of pompon varieties were cut, were considered as blooms. The length of stem of pompons was considered from the base of the branch to the top of the terminal bloom. The data presented are for one of the varieties used in each test. Other data are omitted to conserve space.

Results

The object of the first test was to determine the effects of various kinds of black cloth. Twelve or sixteen plants of each of eight standard varieties were used in each test.

The types of cloth used with counts of threads to the inch were (a) black sateen, 68 x 104, which had been used the year previous and washed twice; (b) unused black sateen, 68 x 104; (c) unused black sateen, 64 x 88; and (d) new black cloth, plain weave, 68 x

72. The treatment was started July 25 and the results with the variety Silver Sheen appear in Table I.

TABLE I—TYPES OF BLACK CLOTH

Cloth Type	Thread Count per Inch	Date First Buds Were Taken	Date First Buds Showed Color	Date First Blooms Were Cut	Cutting Period (Days)	Average Stem Length (Ins.)	Average Flower Diameter (Ins.)
Sateen used	68x104	*A–15	A–29	S–6	17	46	4.7
Sateen new	68x104	A–12	A–28	S–6	17	46	4.7
Sateen new	64x88	A–12	A–31	S–6	20	44	5.0
Plain.......	68x72	A–17	S–3	S–20	13	46	4.9
Check.....		S–12	O–9	O–21	8	65	4.9

*A—August; S—September; O—October.

All sateen cloths were equally effective in producing early blooms. The plants treated with black cloth, plain weave, did not bloom as early and as uniformly as plants treated with black sateen.

Black sateen of 68 x 104 was also compared with a black costume cloth of 54 x 54. Six varieties were grown. The black sateen was much more effective than the black costume cloth as will be seen in the data in Table II for the variety October Rose.

TABLE II—BLACK COSTUME CLOTH VS. BLACK SATEEN

Cloth Type	Thread Count per Inch	Date First Buds Taken	Date Color Showed in First Buds	Date First Blooms Were Cut	Cutting Period (Days)	Average Stem Length (Ins.)	Average Flower Diameter (Ins.)
Sateen.....	68x104	*A–10	A–24	S–9	11	31	5.2
Costume...	54x54	A–21	S–9	O–3	8	35	5.4
Check.....	———	S–12	O–5	O–20	9	51	5.8

*A—August; S—September; O—October.

Effects of a Few Nights of Darkening—Fifteen plants of each of six pompon varieties were given the last pinch July 5 and the short-day treatments continued (1) until color was showing, (2) for 15 successive nights, (3) for 10 successive nights, and (4) for 5 successive nights. The data obtained with the variety Uvalda appear in Table III.

TABLE III—EFFECTS OF A FEW NIGHTS OF DARKENING

Treatment	Date First Buds Appear	Date Color Showed in First Buds	Date First Blooms Cut	Period of Cutting (Days)	Average Number Stems per Plant	Average Number Blooms per Stem	Average Stem Length (Ins.)
Darkened to color..	*A–3	A–23	S–5	14	9.1	6.8	17.2
Darkened 15 nights	A–5	S–12	O–6	18	7.0	4.2	18.2
Darkened 10 nights	A–10	O–8	O–18	6	6.2	9.5	26.1
Darkened 5 nights	S–7	O–8	O–18	6	8.0	4.2	19.9
No treatment......	S–7	O–8	O–18	6	6.2	7.2	26.4

*A—August; S—September; O—October.

Plants which were darkened 15 nights or less formed buds somewhat later than those treated every night until color was showing in the buds. In the majority of cases the time of bloom of the plants darkened for 15 nights or less was not earlier than that of the plants which were given no treatment. Some plants which were given this short-time treatment and which started to bloom earlier than the check plants bloomed over a much longer time and the last flowers were cut at approximately the same time in both cases. Five nights of darkening was sufficient to cause the terminal flower buds to form. These remained, moreover, undeveloped, and vegetative growth came from below them. This produced flower buds and blooms in normal season, although the undeveloped buds remained visible until the blooms were cut.

Plants darkened 10 successive nights formed flower buds about half way down the stem but the remainder grew vegetatively and bloomed in normal season. The early buds remained undeveloped at the time the normal buds were fully open. Plants darkened for 15 nights formed flower buds nearly all the way down the stem. Most of these remained dormant until the days were of the proper length for normal blooming at which time some of them developed. Plants darkened until color was showing in the buds produced normal blooms. In the majority of cases the number of stems per plant were increased by the treatments. The greatest number of stems developed when the plants were given short-day treatment until color was showing in the buds. The number of blooms per stem was decreased by the treatment. The greatest decrease occurred when the plants were darkened for 15 nights, a part of which may be accounted for by the number of undeveloped buds on the stem at the time of cutting. The next greatest decrease in number of blooms per stem occurred when the treatment was continued for 5 successive nights. An increase in the number of blooms per stem occurred when the plants were treated for 10 successive nights.

Effects of Time of Propagation—To determine effects of the time of propagation on the time of bloom, length of stem, branching, and other characteristics, 15 or more plants of each of five varieties were propagated February 15, March 1, 15, and 30, and April 15. The last pinch was given July 10. The plants propagated February 15 were not darkened whereas all others were subjected to the usual short-day treatment starting July 25. The data for the variety Helen Hubbard appear in Table IV.

The time of bloom was not affected by the date of propagation. The number of branches was increased by the cloth treatment even when the plants were propagated 2 months later than the plot which was not darkened. The number of branches cut was greatest when the plants were propagated March 15 or 30. The difference in the number of blooms per stem and the stem length is not significant.

TABLE IV—EFFECTS OF TIME OF PROPAGATION

Date Propagated	Date First Blooms Were Cut	Cutting Period (Days)	Ave. Number Stems per Plant	Ave. Number Blooms per Stem	Average Stem Length (Ins.)
Feb. 15*....	†N–11	6	4.7	8.7	30.9
Mar. 1......	O–6	15	6.1	8.6	25.2
Mar. 15.....	O–6	15	6.6	9.2	24.8
Mar. 30 .. .	O–6	15	6.3	8.8	23.8
Apr. 15...	O–6	15	6.1	8.8	23.0

*Not darkened.
†O—October; N—November.

Effects of the Time of the Last Pinch—To determine effects of the time the last pinch is made on the time and quality of bloom, 15 plants of each of five varieties were given the last pinch in the various plots on June 25, July 5, and July 15, respectively. All plots were darkened as usual starting July 15. Data for the variety Izola appear in Table V.

TABLE V—EFFECTS OF TIME OF LAST PINCH

Date of Last Pinch	Date First Blooms Were Cut	Cutting Period (Days)	Ave. Number Stems per Plant	Ave. Number Blooms per Stem	Average Stem Length (Ins.)
June 25.....	*S–20	9	8.0	9.7	17.2
July 5......	S–20	13	10.5	7.7	15.8
July 15......	S–19	14	11.4	7.1	13.5
July 15.....	N–7	14	5.2	13.8	29.3

*S—September, N—November.

The date of bloom was not affected by the time the last pinch was made. However, the cutting period was shorter when the last pinch was made June 25. Later pinching increased the number of stems which developed but reduced the number of blooms per stem and the stem-length.

The Production of Summer Cut Flowers Under Cloth

By KENNETH POST, *Cornell University, Ithaca, N. Y.*

ABSTRACT

The complete paper is to appear as an extension bulletin from the Cornell University Agricultural Experiment Station.

MANY varieties of plants which are commonly grown for summer cut flowers were grown under "aster cloth," which is a reinforced cheese cloth having a thread count of 22 x 22. The production, stem length, and flower diameter were compared with that of the same varieties grown with no protection. The length of stem and size of flower were increased on all varieties when grown under cloth. Asters, chrysanthemums, snapdragons, calendulas, sweet peas, dahlias, hunnemanias, and pentstemons were benefited to the greatest extent of the plants grown and appear to have the greatest possibilities for commercial cut flower purposes grown under cloth. Gladiolus, lupines, and larkspur were benefited to a lesser extent but showed some improvement over unprotected plants. Centaureas, didiscus, salpiglossis, scabiosas, and helichrysums are generally less grown commercially but were greatly benefited by the treatement. The average stem-length of hybrid tea rose varieties was increased 3 inches. Zinnias, marigolds, gypsophila and clarkia produced stems which were too weak for commercial purposes.

The cloth protected the plants from such insects as leaf hoppers, beetles, bees, tarnished plant bugs, and larvae of various moths. Yellows was completely absent under cloth. The lessened air circulation under cloth permits a more thorough and uniform covering of the plants with fungicide. Snapdragon and aster rusts, rose black spot, and mildew were no more troublesome under cloth than with no protection. No injury to the blooms or foliage by sun, wind, or rain occurred on plants grown under cloth. The effect of the cloth on the growth of plants will doubtless vary from year to year depending upon soil and local climatic conditions.

Studies of the Growth of Annuals and Pompon Chrysanthemums Under Cloth Enclosures

By Alex Laurie, *Ohio State University, Columbus, O.*

WORK previously reported by Jones (2) and by Post (4) indicated that structures of tobacco cloth (22 mesh to the inch) were satisfactory in the prevention of aster yellows. Post showed further that exclusion of many troublesome pests, under such conditions was conducive to better development of a number of annuals.

Tests conducted at the Department of Horticulture grounds at Ohio State University, but under the auspices of the Ohio Agricultural Experiment Station, were undertaken not only from the standpoint of pest and virus control, but also to determine the factors responsible for the greater development of plants under cloth.

Results

Asters—Strains resistant to yellows were tested in comparison with the non-resistant kinds. The seed was sown April 15; the plants were then "pricked off" into 2½-inch pots and were planted in the cloth house May 21. The plants were set in beds 5½ and 6½ feet wide, placing the plants 12 x 12 inches. Three plots of 22 varieties each were placed under yellow, and white cloths and one in the open. The yellow coloring was due to a preservative and also served to reduce light intensity.

The data for asters showed that both yellow and white cloths produced longer stems, larger and better colored flowers, than the checks. The "yellows" was eliminated entirely but susceptibility to aster wilt increased under cloth. In most instances longer stems and larger flowers resulted under yellow cloth than under white.

Annuals—Thirteen varieties of annuals were planted under each of the three treatments, namely, white cloth, yellow cloth, and out of doors. All annuals were planted from 2½-inch pots the latter part of May.

These data indicate that although the production was somewhat variable the length of stem and the diameter of flowers were greater in plots under cloth. The stiffness of stem and the quality of the flowers under cloth were superior to those grown outdoors, while the coloring of the flowers was more intense.

Pompon Chrysanthemums—Eleven varieties of pompon chrysanthemums were grown in plots under yellow cloth, white cloth, and outdoors. Half of each plot was shaded with black sateen cloth from July 15 to August 30, to reduce day length to 10 hours. The cloth was applied at 5 P. M. and removed at 7 A. M. Table III shows the results of the test.

TABLE I—COMPARISON OF THE PRODUCTION OF DISEASE-RESISTANT AND NON-RESISTANT STRAINS OF ASTERS GROWN UNDER YELLOW CLOTH, WHITE CLOTH, AND OUTDOORS

Variety	Wilt Resistance (Per cent)			Average No. Flowers per Plant			Average Stem Length (Ins.)			Average Flower Diameter (Ins.)		
	Yellow	White	Open	Yellow	White	Open	Yellow	White	Open	Yellow	White	Open
Ball's White (Non-Res.)	71	60	—*	7.2	5.9	.3	27.8	21.6	15.1	3.6	3.3	3.0
Ball's White (Res.)	40	25	—	3.3	3.1	—	28.2	20.0	—	3.5	3.3	—
Crego Shell Pink (Non-Res.)	85	91	—	8.2	7.4	—	31.2	25.6	21.5	4.0	3.6	4.0
Crego Rose Pink (Non-Res.)	71	62	—	7.7	6.9	—	28.9	24.1	—	3.5	3.3	—
Crego Deep Rose (Res.)	62	68	—	5.9	6.4	.8	28.7	28.6	13.1	3.4	3.5	3.3
Early Royal Purple (Non-Res.)	100	88	—	26.6	16.7	6.3	18.4	22.3	16.0	2.5	2.8	2.5
Early Royal Purple (Res.)	87	100	—	16.9	18.7	9.6	24.6	22.7	18.0	2.7	2.6	1.9
Queen of the Market Purple (Non-Res.)	100	100	—	13.8	14.3	8.6	19.2	17.6	16.0	2.5	2.3	1.7
Queen of the Market Dark Blue (Res.)	100	100	—	14.2	16.8	9.5	22.7	22.1	15.6	2.2	2.2	2.0
Astermum (Res.)	90	60	—	14.2	14.9	2.6	24.8	20.2	14.0	3.1	2.9	2.9
Amer. Branch Semple Pink (Res.)	56	60	—	6.2	7.3	.3	26.4	25.6	11.6	3.3	2.9	3.0
Amer. Branch Azure Blue (Res.)	36	43	—	3.9	4.9	—	27.7	24.5	—	3.3	2.8	—
Amer. Branch Phlox Pink (Res.)	33	80	—	4.7	5.5	—	26.2	23.2	—	3.0	3.0	—
Calif. Giants Light Blue (Non-Res.)	53	60	—	3.5	4.8	—	26.3	25.5	—	3.7	3.5	—
Calif. Giants Dark Purple (Non-Res.)	30	30	—	2.5	4.2	—	24.9	24.0	—	3.2	2.9	—
Early Beauty Crimson (Res.)	67	66	—	5.6	7.1	—	32.8	30.1	—	3.0	2.7	—
Ostrich Feather Deep Rose (Res.)	26	40	—	2.5	4.1	—	29.6	29.2	12.0	3.7	3.6	3.5
Comet Pink (Res.)	80	97	—	16.0	18.4	2.1	22.1	21.6	14.0	3.0	3.0	2.5
New Giant Calif. Sunshine (Non-Res.)	77	90	—	8.2	8.0	.1	24.9	24.3	13.5	3.2	3.0	3.0
Vaughan's Sunshine (Non-Res.)	37	96	—	10.5	20.5	.9	23.8	24.8	14.0	3.0	2.8	2.5
Heart of France (Non-Res.)	57	83	—	7.4	11.4	—	23.7	23.5	10.5	2.6	2.6	2.5
Heart of France (Res.)	77	77	—	10.2	8.4	—	21.8	23.7	12.0	2.7	2.7	2.7

*Plants were removed before wilt was present due to the presence of yellows.

TABLE II—EFFECT OF CLOTH HOUSE ON MISCELLANEOUS ANNUALS

Variety	Av. No. Flowers per Plant			Average Stem Length (Ins.)			Av. Flower Diameter (Ins.)		
	Yellow Cloth	White Cloth	Open	Yellow Cloth	White Cloth	Open	Yellow Cloth	White Cloth	Open
Antirrhinum majus var. Cheviot Maid	18.0	26.8	20.0	14.5	16.8	10.7	—	—	—
Antirrhinum majus var. Rose Queen...	9.9	8.7	7.3	13.6	14.6	9.7	—	—	—
Calendula officinalis var. Ball's Gold...... ...	9.7	10.0	7.0	21.2	17.8	11.2	2.3	2.3	2.0
Centaurea suaveolens..........	16.8	18.5	17.4	9.5	8.7	8.2	1.6	1.5	1.5
Chrystanthemum segetum.......	18.9	34.0	11.1	16.1	13.9	8.2	1.8	2.0	1.3
Crepis...	69.1	71.2	29.3	12.2	12.5	8.0	1.5	1.3	1.0
Cynoglossum amabile.......	6.9	7.8	8.8	29.0	25.7	21.6	—	—	—
Dahlia var. Jersey Beauty.......	21.7	33.0	13.0	14.3	7.8	7.0	6.5	4.5	3.0
Dahlia var. Princeps Victoria..	41.8	37.0	9.7	11.2	11.5	6.0	3.0	3.0	2.5
Pentstemon gloxinioides var. Red Sensation	5.3	5.7	1.1	28.5	29.6	16.0	—	—	—
Scabiosa Azure Fairy.........	25.1	40.8	25.3	10.8	12.2	10.0	1.9	1.9	1.5
Tagetes erecta var. Guinea Gold..	72.4	75.5	40.8	16.9	14.6	8.5	3.0	2.1	2.0
Zinnia elegans...	12.5	8.4	10.1	25.1	28.2	10.9	3.1	3.6	2.3

Data show that pompon chrysanthemums may be grown in cloth enclosures satisfactorily and earliness of flowering may be secured by shortening the day-length with black cloth. The difference in earliness of flowering under yellow cloth may be attributed partially to a heavier grade of black cloth used than under white tobacco cloth and partially to less light intensity. Length of stem and the quality of flower were improved over those grown in open ground, and, in addition, tarnished plant bug and other pests were eliminated from consideration. Outdoor plots showed so much damage and distortion from insect attacks that the flowers were not usable. Mensa and Maple leaf varieties did not respond as favorably to shading as the other varieties.

The plots receiving treatment under tobacco cloth but without reduced day-length flowered very well under both cloths. The color of the flowers on these plots was much more intense than the same varieties grown under glass. Planting pompons under cloth without reducing the day-length with black sateen is not recommended. No heavy frosts occurred during the past season until after the crop was cut, but if frosts should come before October 15, no crop could be expected from plants grown in the open.

TABLE III—EFFECT OF SHORT DAY TREATMENT ON POMPONS UNDER YELLOW CLOTH, WHITE CLOTH, AND OUTDOORS

Variety	Date of Cutting						Average Stem Length (Ins.)					
	Yellow		White		Open		Yellow		White		Open	
	Short Day	Normal Day	Short Day	Normal Day	Short Day	Normal Day	Short Day	Normal Day	Short Day	Normal Day	Short Day	Normal Day
Capt. Cook.	Sept. 13	Nov. 1	Sept. 19	Nov. 1	——*	——*	39	53	39	50	—	—
Ethel.......	Sept. 9	Oct. 29	Sept. 15	Oct. 19	Sept. 21	—	31	45	31	42	19	—
Firebird....	Sept. 28	Oct. 21	Sept. 17	Oct. 21	Oct. 6	—	32	42	25	40	21	—
Irene.......	Sept. 5	Oct. 19	Sept. 9	Oct. 19	Oct. 6	—	30	42	31	40	12	—
Izola.......	Sept. 15	Oct. 1	Sept. 28	Oct. 1	Oct. 29	—	30	41	28	41	20	—
Maple Leaf	Sept. 28	Oct. 31	Sept. 28	Oct. 31	——	—	29	40	30	40	—	—
Mensa......	Sept. 19	Nov. 3	Sept. 17	Nov. 3	——	—	36	49	27	48	—	—
Rodell......	Sept. 7	Oct. 14	Sept. 9	Oct. 14	——	—	31	42	26	40	—	—
Silver Ball ..	Sept. 5	Oct. 19	Sept. 9	Oct. 19	Oct. 6	—	36	48	34	45	18	—
Varsity....	Sept. 9	Oct. 25	Sept. 16	Oct. 25	——	—	31	47	29	45	—	—
White Doty.	Sept. 13	Oct. 31	Sept. 17	Oct. 31	Sept. 29	—	31	42	28	42	19	—

*Flowers were disfigured due to attack by tarnished plant bug.

The value of being able to grow the early pompons out of doors is considerable. The greenhouse benches may be planted with late flowering varieties of chrysanthemums or other crops such as carnations, snapdragons, calendulas or other annuals that would flower during the darker months of winter.

To determine the effects of temperature, light intensity, and moisture upon the growth of the plants studied under cloth enclosures, records were taken. The temperatures under cloth were from 1 to 3 degrees higher than out of doors. This difference may be ascribed to a reduction of air circulation under cloth.

Light intensity was measured with slowly sensitized paper placed in graduated frames. The records showed that light intensity out of doors was 12 units higher than under yellow cloth and 6 units higher than under white cloth. It was also found that when light intensity was high, the difference between the two cloths was less than when the light intensity was low.

Soil moisture remained higher under cloth than outdoors. The amount of water applied to outdoor plots was three times as great as that under cloth. Relative air humidity varied from 2 to 10 per cent higher under cloth than out of doors.

The combination of higher temperatures, lower light intensity, and greater humidity was undoubtedly responsible for the better development of the plants under cloth enclosures. However, the reduction of light was not sufficient to produce soft, succulent growth.

The following is a list of materials used in constructing a cloth house 90 feet by 32 feet wide:

18 10-foot cedar posts at 69 cents	$12.42
22 4 x 4 x 24-inch pine	2.80
256 feet 6 x ¾-inch redwood boards	11.56
24 feet 2½ x ¾-inch redwood boards	.63
45 pounds No. 10 wire at 4 cents	1.80
519 square yards cloth at 5 cents	25.95
String, nails, hinges, screws	.42
36 hours labor for construction at 35 cents	12.60
28 hours labor for sewing at 35 cents	9.80
Total	$77.98

The cost per square foot, up to the time of planting, amounted to 2.5 cents. This amounts to 3¼ cents per plant, which allows for the waste space used by walks.

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Effects of Day Length on Growth of Orchid Seedlings[1]

By J. C. Ratsek, *Cornell University, Ithaca, N. Y.*

THE purpose of this work was to determine if long periods of daylength hastened the growth of orchid seedlings.

Series I. Tubes of orchid seedlings were used that had been germinated according to the method of Knudson (1). The nutrient media contained 1.5 per cent sugar. The seedlings used were D1—*Laelia pacavia* (Mrs. Hamilton Smith) x *Cattleya* Harold and D2—*Laelia anceps* Stella x *Cattleya* Enid *alba.*

The tubes were kept in a case in the University greenhouses and shaded with cheesecloth when necessary. A relatively constant temperature was maintained by proper aeration, and heating units connected to a thermostat. The temperature averaged 85 degrees F during the day and 72 degrees at night during September and October and 78 and 68 degrees throughout the winter.

The normal daylength was supplemented by a 40-watt Mazda lamp suspended 30 inches above the tubes. The light was kept burning in the evening to bring the total hours of daylight to the requirements of the experiment. The normal daylength for the controls varied from 16 hours and 20 minutes in August, to 11 hours in December. The experiment was begun August 5, 1930, and continued for approximately four months. At the end of that time 100 seedlings were taken at random from each tube and weighed. The results which follow indicate only the averages of all determinations.

	Average Fresh Wt. per 100 Seedlings (Mg.)		Gain 20-Hour Over Normal	
	Control	20 Hour	(Mg.)	(Per cent)
D1	225	306	81	31
D2	179	246	67	41

Series II. Flasks were used containing seedlings transplanted December 2, into a medium similar to that in Series I, but without sugar. The seedlings were those of the above series, keeping the original letter and number for identification but adding N or 20 to indicate previous treatment. The D1 seedlings were taken at random in groups of 100 each, weighed and placed in the flasks. The D2 seedlings were selected to get 50 of the largest, weighed and transplanted to the flasks. The treatments were 20 hours with temperature control as before, but one group received additional light from a 25-watt Mazda lamp, and the other from a 60-watt lamp. The distance from the lamps to the seedlings was increased

[1]The original report is on file in the library at Cornell University, and this paper is a short summary of the methods used and the results obtained.

to 38 inches because of the additional heat that came from the larger lamp. The experiment was continued from December 5 to April 26. The normal day varied from 11 hours in December, to 15 hours and 45 minutes on April 25. The results of this experiment were as follows:

Lot	Treatment	Initial Fresh Wt. of Seedlings (Gms)	Final Fresh Wt. of Seedlings (Gms.)
D1-N	Normal Day	.227	2.840
	20 Hr., 60 Wt.	.240	3.030
D2-20..	Normal Day	.241	1.499
	20 Hr., 25 Wt.	.248	2.092
	20-Hr., 60 Wt.	.250	1.860

There was a consistent gain in rate of weight-increase of the treated seedlings over the controls. More important, however, was the type of growth, especially in D2. The roots were long and thin, the total length per plant in the 20-hour light exposure period being double the length per plant in the control. Furthermore, the roots all grew from the base of the plants, whereas in the controls they developed both from the base and from the axils of the lower three leaves. There was also a difference in the type of growth of the tops. In the 20-hour light exposure the leaves were less in number, but 50 per cent longer than in the controls. Furthermore, there was but one growing point in the long-day plants; namely, the apical bud, but there were three to four, in the controls because of the development of lateral buds.

Series III. This experiment began August 1931 and continued 2 months. The seedlings used were B3—*Cattleya aurea* x *Cattleya labiata* and Ph 19—*Phalaenopsis* Gilles Gratiot. The treatment of the seedlings was the same as in Series II but light was supplied from a 75-watt Mazda lamp placed 40 inches above the flasks. The light exposures of the plants were for 20 and for 12 hours, the latter group being shaded for the necessary period with black cloth during the first part of the experiment when the normal day was longer than 12 hours, and later exposed to light from a 75-watt lamp when the days became shorter.

The average green weight per plant for the B3 seedlings was 7.2 mg. for the 12-hour group, and 14.0 mg. for those of the 20-hour series; an increase of nearly 100 per cent.

The average green weight per plant for the Ph 19 seedlings was 16.0 mg. for the 12-hour plants, and 20.0 mg. for those of the 20-hour series; an increase of 25 per cent.

Summary

(1) Long-day treatment increased the fresh weight of orchid seedlings. This was greatest during the winter months when the

seedlings were grown on a sugar nutrient media. (2) Long-day exposure increased the height of orchid seedlings and the growth of the apical bud as opposed to short-day exposure which induced growth of lateral buds. (3) Long-day exposure induced growth of roots that were long and thin, and these grew from the base of the seedlings. (4) Short-day exposure induced growth of roots that were tuber like, short and thick, and they developed from the base of the plant, or from the axils of the lower leaves. (5) There was no significant difference in growth of the seedlings between those exposed to light from a 25-watt lamp and those from a 60-watt lamp.

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The Influence of Aluminium on the Flower Color of Hydrangeas[1]

By R. C. Allen, *Cornell University, Ithaca, N. Y.*

Abstract

The complete paper will appear in the Contributions from the Boyce Thompson Institute, Yonkers, N. Y.

FURTHER studies on the cause of the change in color from pink to blue in greenhouse hydrangeas (*Hydrangea Macrophylla* DC varieties) are reported. Results are given from experiments with sand cultures, soil treatments, and other methods which show that aluminum, rather than iron or hydrogen ion concentration, is the element directly responsible for the color change.

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[1]Joint contribution from the Boyce Thompson Institute for Plant Research, Yonkers, New York, and Department of Floriculture and Ornamental Horticulture, Cornell University, Ithaca, New York.

Preliminary Experiments on Nutrients and the pH of Water and Nutrients as They Affect Growth of Orchid Seedlings

By J. C. Ratsek, *Cornell University, Ithaca, N. Y.*

It was observed that orchid seedlings grown on an osmundine media containing one-fourth German peat, made a better growth than those in osmundine alone or in osmundine and live sphagnum moss. Three possibilities suggested themselves as explanations for this:

1. *The high water holding capacity of the peat.*
2. *The reaction of the peat.*

Peat aids in keeping the reaction of the media at a lower level than does osmundine alone, or osmundine and sphagnum as is evident from the following pH values.

Tap water	7.0–7.2
Osmundine recently planted	5.7
Osmundine planted at least 1 year	7.2
Osmundine and sphagnum	5.5
Osmundine and peat	5.0
Osmundine not planted	5.2
German peat	4.0

3. *The nutrient value of peat.* No clear evidence as yet has been presented as to why peat is beneficial. Earlier studies indicated that nitrogen, present in fairly large quantities, was an important factor. Subsequent work by Fuestel and Byers (2), however, indicates that much of the nitrogen is in an insoluble form and consequently not readily available.

Experiments were therefore undertaken to determine just how important the two factors, pH value and nutrients, are in the growth of orchid seedlings under usual conditions.

Pots 2½ inches in diameter containing fifteen seedlings of the hybrid (*Cattleya aurea* x *Cattleya Labiata*) 15 months old, were selected for uniformity and arranged in seven series of three pots each, and watered with buffered rain water at pH 3, 4, 5, 6, 7, 8 and check at pH 6.6 respectively. McIlvaine's standards were employed to make up the buffers which were used at the rate of 20 cc per liter. The plants were watered with the buffered water once a week beginning May 20, 1932, and continuing for 18 weeks. The temperature maintained throughout this period was 68 degrees F at night and 78 to 85 degrees F during the day, with a relative humidity of 50 to 60 during the day and 70 to 80 at night. The seedlings were sprayed with an atomizer two to three times a day with unbuffered rain water.

The results are only suggestive since the range between the pH of the solution added and the final pH of the media was wide, due, at least partly, to the destruction of the citric acid by organisms. Since it is not known how rapidly this destruction occurred, the results must be considered in terms of the complete range of pH as follows:

Initial pH	Final pH	Fresh Weight 15 Seedlings (Gms.)	Per cent Surviving
3	5.1	0.84	60
4	6.1	0.60	100
5	6.6	0.61	100
6	7.0	0.56	100
7	7.5	0.43	46
8	7.7	0.74	100
Check—6.6	5.3	0.76	100

Generally the weakest growth occurred at pH 7.0–7.5 with an increase on the alkaline and on the acid side. The 40 per cent loss of seedlings in the lowest range is not explainable unless it may have been due to a slight toxicity of the citric acid.

A second experiment was started at the same time with four series of 11 pots each, using 2½- year-old pots of the following varieties:

Laelia pacavia (Mrs. Hamilton Smith) x *Cattleya* Harold
Laelia anceps—Stella x *Cattleya* Enid *alba*.
Cattleya Enid x *Octave* Doin.

The pots were of the same size as in the first experiment but contained 3, 4, 6 or 8 plants, depending upon their size. The treatments for the four series were as follows:

1. Buffered full nutrient at pH....................... 4.5
2. Buffered full nutrient at pH....................... 5.0
3. Buffered full nutrient at pH....................... 5.5
4. Check—tap water at pH 7.1

The full nutrient used was Knudson's solution B (1) at double the strength recommended for orchid germination media. The solutions were buffered with citric acid using the K_2HPO_4 in the solution as the base. This experiment ran for 13 weeks, when weights, measurements, and total nitrogen determinations were made. The results of the Kjeldahl determinations are expressed as percentage of dry matter. The results follow:

Initial pH	Final pH	Leaf Area per Plant (Sq. Cm.)	Root Length (Cm.)	Fresh Wt. per Plant (Gms.)	Nitrogen (Per cent)
4.5	5.4	14.66	23.90	1.70	2.32
5.0	5.6	14.44	24.17	1.72	2.01
5.5	5.5	14.46	24.24	1.80	2.13
Check 7.1	6.4	8.51	24.35	1.23	1.20

The growth and appearance of the three nutrient-treated series was not significantly different and the leaves were all deep green, whereas the leaves of the check were yellow-green. The ratio of root length to leaf area was .604 in the nutrient series and only .351 in the check. It is evident that in the absence of sufficient nutrients, root elongation proceeds more rapidly with a subsequent decrease in top growth.

A third experiment was set up using plant material similar to that of the second experiment. The plants were watered with tap water acidified with sulfuric, phosphoric, or nitric acids to pH 5.0, and tap water of pH 7.1 was used as the check. The experiment began May 20 and continued for 24 weeks. The results follow with nitrogen expressed as percentage of dry matter.

Treatment	pH	Fresh Wt per Plant (Gms.)	Top/Root Weight Ratio	Nitrogen (Per cent)	Final pH
HNO_3	5.0	1.58	3.03	1.74	5.9
H_3PO_4	5.0	1.23	1.77	1.17	6.3
H_2SO_4	5.0	1.00	2.21	1.03	6.0
Check	7.1	1.16	1.90	1.13	6.2

The phosphoric acid series showed no significant increase over the check. The difference between the check and the series with sulphuric acid is on the border line of significance with odds of 25:1. If one considers this as significant, the decreased growth is probably due to the sulfate ion acting as a toxic agent as found by Volz and Burke (3). The final pH of this series was lower than the check, but only slightly higher than the nitric acid treated series, so that unless there was a toxic action, one would expect the weight to approximate the check. If, however, the pH was a factor, it should even exceed the check. It is evident that the nitrate was the important factor in the nitric acid treated series. It, and not the pH, is responsible for the increased growth.

The seedlings watered with the nitric acid solution were dark green. The phosphoric acid group was slightly lighter green, whereas the sulfuric acid group and the check were yellow-green. This became evident early in the experiment so that another experiment was begun using full nutrient as in the second experiment, ammonium sulfate alone, and tap water as the check. The full nutrient contained ammonium and nitrate nitrogen, the latter but slightly in excess of the former. KH_2PO_4 was substituted for K_2HPO_4 to increase the acidity. The ammonium sulfate was added at the rate of 2.2 grams per liter to equal the total nitrogen-content of the full nutrient. The initial pH of the full nutrient solution was 4.6 and that of the ammonium sulfate solution was 5.3. Similar plants were used as in the previous experiment with but nine of eleven pots in each series. The results follow:

Treatment	Initial pH	Final pH	Fresh Wt. per Plant (Gms.)	Top/Root Weight Ratio	Nitrogen (Per cent)
Full nutrient	4.6	5.4	2.39	1.69	1.91
$(NH_4)_2SO_4$	5.3	5.0	1.47	1.33	1.21
Check......	7.1	6.6	1.19	0.87	0.83

The experiment was planned to determine the effect of the ammonium sulfate which is used by some orchid growers to obtain increased acidity in the orchid media, as well as a nutritional effect from the ammonium. The above results indicate that ammonium sulfate is not nearly as effective as a full nutrient solution at the pH employed. Some of this retarding effect on growth may be due to the sulfate ion but it is more probable that it is due to a relatively low pH for the assimilation of the ammonium ion (4) as well as to the lack of other elements necessary to plant growth that are present in the full nutrient but absent in the ammonium sulfate solution.

Summary

A pH at the neutral point or slightly above was not conducive to growth of orchid seedlings. Water acidified to a pH of 5.00 with nitric acid was more effective in stimulating growth than tap water alone. Ammonium sulfate alone was effective as a nutrient, but not as much so as a full nutrient in spite of the apparently more favorable pH it creates. Nitrogen increases top growth as compared to root growth.

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Growth Responses of Pin Oaks Due to Fertilizers, Pruning, and Soil Conditions

By DONALD WYMAN, *Cornell University, Ithaca, N. Y.*

THE general layout for the experiments reported in this paper was described in detail in the Proceedings for 1931. The results here reported are for growth in 1932 but appear to warrant definite conclusions on the current year's growth at least. All measurements of growth represent total twig elongation as measured over each entire tree.

Some of the results on plot IV differ from those obtained on the other plots. At present no definite reason can be given for this. Pin oaks, however, usually are found native on a wet soil. The plot in question is lower and tends to remain wet longer in the spring than the others. The top soil may be deeper or the water table higher than on the other three plots. Several other factors may combine to cause this variation, which is principally in the fertilizing and planting responses.

TABLE I—EFFECT OF MANNER OF PLANTING ON TOTAL LINEAR GROWTH (IN FEET) SECOND GROWING SEASON (1932)

Soil	Time of Planting	(A) Loose Planting		(B) Rough Planting		(C) Ordinary Planting		Odds in Favor of C over A	Odds in Favor of C over B
			1932	1931	1932	1931	1932		
I. Gravelly	Spring	2.80	8.59	2.35	9.29	4.00	11.18	138:1	3332:1
II. Gravelly	Fall	2.45	9.32	2.13	7.76	2.65	9.55	not significant	not significant
III. Clay . . .	Spring	2.47	9.89	2.94	8.58	2.81	12.12	59.2:1	151:1
IV. Clay . . .	Fall	1.90	17.98*	2.44	25.27*	2.42	14.66*	——	——

*Causes for this response can not be explained definitely as yet.

From the table it is evident that elongation made by spring-planted trees is significantly greater with careful planting (C) than with rough planting (B) or loose planting (A) on both the soil types. In fall planted trees on gravelly soil, there is no significant difference in growth for trees planted by the three different methods. This might be explained by the fact that the soil around the loosely planted trees becomes more packed by winter conditions, and the soil around the rammed trees may become more loosened from alternate freezing and thawing in winter immediately after transplanting. It may be also that in fall planting the roots of trees planted by any method are given time during the late fall, winter, and early spring to establish themselves equally. This may be especially true since the winter immediately after planting (1930) was comparatively mild.

It was shown last year that for the first year of growth (1931) the odds were 69.4:1 in favor of spring planting calculated on the basis of growth alone. This advantage of spring planted over fall planted trees is still apparent the second year (1932) on the gravelly soil. It was shown also in 1931 that for spring planted trees on gravelly soil, the odds, based on total growth, favored the check trees planted in the ordinary manner. From Table I it is apparent that this difference is also significant the second year of growth.

Results with Fertilizers

In the spring of 1932 the pin oak trees used had an average trunk diameter, 2½ feet from the ground, of 1.6 cms. In 1931 ammonium sulphate or ammo-phos was placed in holes 2½ feet from the trunk. It was noted that in certain instances leaf burning occurred in some trees which had the fertilizer applied at time of transplanting but this burning may have been caused by other factors than fertilizers. No deepening of the green color of leaves was observed, however, and results obtained this year indicate that this color change is a perfectly accurate way of distinguishing the fertilized from unfertilized trees.

During the early spring of 1932 some trees were dug up in an effort to find out just how far the roots had spread. In every case it was noted that all new roots were going directly down and none were going out beyond the original diameter of the root ball which varied between 2 and 2½ feet. Consequently it was decided to apply the fertilizer much closer to the trunk, since it was apparent that the trees were taking up no fertilizer either because of the method of application or because of the distance it was placed away from the roots. On May 13, 1932, the fertilizer was again applied (8 ounces of ammonium sulphate per tree to 15 trees, 12.6 ounces of ammo-phos per tree to 15 trees on each of the 4 plots) by dividing the fertilizer ration equally among four holes per tree, each hole 12 inches deep and 1 foot from the tree trunk. Enough water was added to each hole to dissolve the fertilizer in order to make it immediately available to the tree.

Of the 60 trees fertilized on the gravelly soil, 11 later showed leaf injury, 5 eventually dying from the treatment. On the heavy clay soil, 35 of the 60 trees fertilized later showed leaf injury and 25 eventually died. This difference in magnitude of injury produced by the same fertilizer applied at the same time to similar trees but on different soil types, is evidence of the troubles encountered in making blanket fertilizer recommendations for all soil types.

Since this treatment was too strong, other trees which had been planted at the same time and were of the same age and size were fertilized in the following manner: One ounce of ammonium sulphate or slightly over 1 ounce of ammo-phos was placed in each of eight holes per tree, 12 inches deep and 1 foot from the trunk,

at different intervals. One hole was filled June 15, another July 1, and two each on July 15, August 1, August 17. Each application was dissolved in water.

Of 23 trees treated in this manner, not one showed any indication of fertilizer injury even though the same amount was ultimately added as in the May fertilization which killed some trees. During July the leaves on all fertilized trees became much darker than those on the unfertilized trees and their color deepened during the rest of the summer. In August and September one could stand at a corner of the experimental plot and instantly pick out all fertilized trees by this character. During the latter part of October, when the leaves of unfertilized trees were changing color or changing directly to brown, the leaves of fertilized trees remained green at least 1 week longer and then usually changed to much deeper reds and even purples than did those of unfertilized trees.

TABLE II—EFFECTS OF FERTILIZERS ON GROWTH (IN FEET PER TREE) DURING 1932

Soil	Time of Planting	Am. Sul. (D)	Ammo-phos (F)	Check (C)	Odds in favor of F over C	Odds in favor of D over C
I. Gravelly	Spring	15.63	17.96	11.18	114:1	49.3:1
II. Gravelly	Fall	12.61	21.21	9.55	369:1	21.4:1
III. Clay	Spring	17.39	22.43	12.12	713:1	1999 :1
IV. Clay	Fall	14.55	14.16	14.66	——	——

Analyses for total nitrogen of the leaves of fertilized and unfertilized trees have been made and will be reported later.

The reason that some of the trees treated with fertilizer in May died and others apparently thrived might be explained on possible physiological variations in individual trees, soil, drainage, or root distribution. Most of the trees which did not die but had suffered notable leaf injury from the May fertilizer application recovered by the end of the summer and put out normal leaves on secondary or even tertiary growth.

Further studies comparing the effects of applying fertilizer at different seasons are desirable, but in this paper no distinction is drawn between times of application.

From Table II it is evident that in plot II the average increase in growth of the trees treated with ammo-phos is much greater than for those treated with ammonium sulphate. It may be that the ammonium sulphate did some undetected injury to the trees, causing the insignificantly low odds in (D) over the checks (C). However, if all the ammonium sulphate treated trees (D) in the three plots are compared with all the checks (C) in the three plots, the odds are over 9999:1 in favor of the ammonium sulphate treatment.

The odds are likewise over 9999:1 in favor of those trees treated with ammo-phos (F) as compared with the checks (C) when all treated trees on the three plots are compared with all the checks.

No comparison is made at this time between those trees receiving only nitrogen (D) and those receiving both nitrogen and phosphorus (F), though this will be done later.

Consequently there is a decided increase in growth the same year the trees are fertilized. In this connection, it is interesting to note the amount of secondary growth made by all fertilized trees (Table III). All trees were measured June 20 after primary elongation had stopped on most trees. Measurements were taken again November 1, the difference between the two measurements being termed "secondary" growth though this actually included a small amount of "tertiary" growth on some trees.

TABLE III—AVERAGE TOTAL GROWTH PER TREE (IN FEET) BEFORE AND AFTER JUNE 20, 1932

Soil	Planted	All Fertilized Trees (D & F)		All Unfertilized Trees (A, B & C)	
		Before	After	Before	After
Gravelly	Spring	6.99	7.93	9.69	.58
Gravelly	Fall	7.48	8.67	7.57	.45
Clay	Spring	7.30	9.58	5.32	3.51
Clay	Fall	8.55	6.20	10.75	6.47*

*Obviously some soil factor must be responsible for this secondary growth on this plot and hence for the other variations already mentioned.

RESULTS WITH PRUNING EXPERIMENTS

These experiments involved trees larger than those used for the planting and fertilizing experiments. They were pruned in two ways, namely, one lot was left with a definite amount of branches distributed along the trunk, another with the same amount of branches but all at the top of the tree with a long trunk void of branches. A third lot was not pruned when planted. Trees in this experiment were set out only on the two clay soil plots.

TABLE IV—TOTAL GROWTH PER TREE (IN FEET) OF TREES PRUNED WITH BRANCHES ALL AT THE TOP OR DISTRIBUTED ALONG THE TRUNK

Soil	Time of Planting	(J) Branches at Top		(K) Branches Along Trunk	
		1931	1932	1931	1932
Clay	Fall	3.88	17.83	3.20	26.65
Clay	Spring	2.56	13.33	3.57	20.35

Even in the second year growth results are significant. (Table IV.)

For the 1932 growing season, odds in favor of trees with distributed branches (K) over those with branches at the top only (J) are 525:1 for the fall planted lot.

The respective odds for the spring planted lot are 344:1. This is an indication at least of the method which should be used in pruning the long trunk of a young tree.

What is Next in Horticultural Research?

By R. D. Anthony, *Pennsylvania State College, State College, Pa.*

THE present is an opportune time to reflect a bit as to what we have accomplished in horticultural research and where we seem to be going; even to make a guess as to what we may find along the road. Most of us are faced with the necessity of cutting down our research to fit a much reduced budget; some of us may have to prove that our labor is worth the hire in order to continue to receive even a reduced appropriation.

Eleven years ago at the Toronto meeting Dr. W. H. Chandler read a paper on "The Trend of Research in Pomology"—a paper that all interested in horticultural research should read or read again. In his opening paragraph he states: "A discovery of striking or dramatic interest often stimulates research, not alone in the science to which the discovery belongs, but in other related sciences." This is one of the reasons why horticultural research falls in rather well-defined periods. When our Horticultural Departments were first organized, the demand for quick results led to much variety testing, short term fertilizer trials, and tests of miscellaneous spray materials. Out of these came projects in fruit and vegetable breeding, better organized, long-time fertilizer trials and the passing on of much of the insect and disease control to Departments of Entomology and Pathology.

Then came the period when all of us, old and young, set out to collect advanced degrees and with this came an insistent demand for research which could be carried close enough to completion in one or two years to permit the preparation of a thesis. Department research programs were not prepared for this; the inclusion of such studies as fruit bud differentiation, fruit morphology, orchard and marketing surveys could meet but part of this demand.

Thus the stage was set for the enthusiastic reception of the c/n ratio period with the development of the chemical laboratory as an adjunct to every ambitious horticultural department. We are still too close to this period properly to evaluate its results. When this period was just beginning to dominate horticultural research, Chandler, in discussing the value of chemical analyses, stated: "It is needless to say that conclusions based upon such studies were not always correct. Even with our present greatly increased physiological and biochemical knowledge, it is seldom safe to base recommendations as to practice upon such knowledge alone." After more than a decade there seems to be little to add to these statements. If we are disappointed that a favorite method of attack has resulted in such slow progress we should turn again to Chandler and read: "Yet in spite of our faith in the ultimate value of such fundamental studies in the solution of practical problems, we should not expect too much in the way of immediate results.... It is often dangerous to base a recommendation as to a practice upon a fundamental principle.... In fact it seems

probable that the more fundamental the problem studied the greater is the danger of misinterpretation."

Of the minor trends among the major periods, studies in the setting and dropping of fruit, the determination of methods of insuring correctly named nursery stock, improvement in field plot technique, studies of dormancy and the rest period, and the preliminary work on photoperiodism have all contributed worthwhile results.

We shall have to label the present the era of financial stringency. If these trying times bring us into more sympathetic contact with our growers and develop a mutual appreciation of our problems they will be worth all they may cost us. Our first thought should be that this is an emergency period demanding the best we have in helping our growers to find and practice wise economy and to foretell future developments with sufficient accuracy to safeguard the enormous funds invested in horticultural enterprises in our respective states. This is not an easy matter with an industry which has become world wide, with our methods of transportation in a state of flux, and with tariffs, quotas, and embargoes upsetting usual marketing practices.

In times like these we must be able to prove to the most skeptical that we are more than paying our way. It will not save us to say that our work is a long-term problem which will benefit the next generation, if we are successful. Our only justification for undertaking work for the next generation is to show that we are also working successfully on the problems which are worrying this generation. The long-time success of any horticultural department will depend largely on how well its program is balanced with these two types of problems. If we were General Electric stockholders, we should feel that the General Electric research laboratories must be able to show that they have paid good dividends on their cost up to the present and that they can continue to do so in the future. We are members of a group of research laboratories that service an industry in exactly the same sense as do the General Electric laboratories. Unfortunately we are sometimes less intimately in contact with our stockholders.

These depression years will eventually give way to a new period, and department budgets and department programs will become more nearly normal. What are some of the problems which will probably demand attention in these next 10 or 15 years? In the East, at least, we need to place increasing emphasis on the fundamental economy of high yields. We are completing the cycle of cycles and are back again to a study of fertilizers and cultural methods; the progress made in 30 and more years is suggested by the new title—soil fertility problems—and by the fact that we do not look to pure chemistry for help as much as to bio-chemistry and bacteriology. The soil has ceased to be a group of rock fragments; it has become dynamic.

When we appeal to the bio-chemist, the bio-physicist, or the soil bacteriologist for help we find him unprepared to aid us to the extent

we should like. This is too new a field of endeavor for the fundamentals to have been developed. It is doubtful if we can secure much help along this line for some years to come, though certain lines of attack already offer promise. The performance of a soil on incubation under control laboratory conditions may give significant results. It is also possible that a method of studying the CO_2 output of a soil in place may become a valuable tool. Ultimately we must have a much clearer picture of the role of organic matter in the soil.

As soil fertility studies become more and more studies of soil activity, there is an increasing realization of the importance of soil type in horticultural economics. Bound up with both of these problems is the question of water relations in both the fruit and vegetable plantations. A number of record-making dry years in the last decade have emphasized the importance of this last work. It seems possible that we may be able to use much more extensively the time-saving California method of studying water loss in a soil as an index to root presence and activity rather than laborious systems of digging out the roots. The economics of irrigation for the eastern vegetable and small fruit grower are worthy of study; and the influence of the humus content of the soil on rainfall absorption, field capacity of the soil, and rate of water loss need as much study in the East as in the irrigated West.

Ten years ago there was fair promise that our variety lists would become moderately stable. Since then the plant breeder and the sport hunter have started us off on another cycle of variety testing. This is fortunate as the continued prosperity of some of our older fruit regions depends, in no small measure, on finding new varieties better suited to present day market demands.

In spite of the excellent work done in recent years we still have many pollination problems that are unanswered. Also, since evironment seems to be a considerable factor in such work, it will be desirable to continue to check the results of pollination tests in several regions.

The improvement of root stocks is such a long-term project that one might hesitate to continue such work in the face of reduced maintenance but there are two economic factors which justify its continuation. When mature apple trees become so large that they crowd each other with a 40-foot planting, costs of pruning, spraying, and picking are increased and the quality of the fruit decreased. Such troubles as wooly aphis and the various root rots are taking too heavy a toll in many of our orchards. The use of vegetative propagation to produce half-standard or dwarf trees, to maintain any discovered immunity to diseases or insects or to meet some particular soil or varietal requirement eventually will be a common nursery practice, but we of this generation in this country may see only its beginnings. If we find that the use of vegetative roots brings about greater uniformity in commercial plantings, such information will hasten the adoption of this method of propagation.

This body of research workers should consider itself under indictment when any large loss falls upon the horticultural industry which could have been prevented by more adequate research or a more efficient extension agency. In the past the heaviest loss our industry has suffered has been due to the unwise location of a vast number of fruit plantings. We should not blame ourselves too severely for these early failures but, if we are to avoid blame in the future, both research and extension agencies must give more attention to questions of proper location and site.

We may expect the study of leaf performance to receive increasing emphasis. Why is one variety less injured by drought than another? What is the complete story of photosynthesis under reduced water supply? What are the effects of sprays on leaf activity? Why does one variety seem to need a larger leaf surface to produce a crop than another? Is CO_2 fertilization a commercial possibility in the greenhouse? These are but a few of the pressing questions.

To a very large degree we have passed to other departments questions relating to spraying. The very fact that so many departments are involved has frequently been a handicap to fruit growers. It is highly desirable that the research horticulturist continue to be interested in spraying. I expect to see a complete change in our spray materials in the near future; our insistence upon the necessity of doing away with spray burn to preserve the full activity of the leaf will be a material factor in this change.

It is highly desirable that we accustom our fruit growers to making more intensive studies of tree growth in their orchards. Yield must be the ultimate criterion of any orchard practice but it is almost the last factor to respond to a fertility change and consequently its use as the sole guide is too slow for efficient management. The responsibility rests upon us to determine what growth factors are most responsive to changed conditions, the correlation between these factors and yields, and then to express the results in terms usable by the average fruit grower.

Very few of us have the ability to be both good horticulturists and also good biochemists or physiologists and we are hired to be good horticulturists. Our need for help from departments of chemistry, physiology, and soils is urgent but frequently we can secure it more economically and of a higher quality when the work is done in connection with the regular laboratories of those departments. Such cooperation should be specifically arranged with the definite designation of the individuals to carry on the work, the proportion of their time to be devoted to it and a clear statement made of the responsibility resting upon each department. At Pennsylvania State College one member of the Department of Agricultural Biochemistry, working in a laboratory of that department, is detailed for full time work for the Horticultural Department. We are also attempting to secure similar technical help in soil chemistry and recently have maintained a graduate student in the plant physiology laboratory for work on a pomological problem.

Until quite recently many of us have avoided that group of problems dealing with marketing:—storage, transportation (both rail and truck), market preferences, marketing agencies, and manufactured products. This has laid us open to much criticism from our growers and, in some cases, has resulted in placing this type of work in departments of economics or farm management. If we are to serve our industry we should be interested in the full field to the greatest extent our finances will permit. It would be extremely unfortunate if we permitted any of these problems to slip entirely away from departments of horticulture though the cooperation of other departments may be highly desirable.

The statement in the last two paragraphs would seem contradictory. If we assume that the function of a Horticulturist is to interpret, in terms that commercial growers can understand, the fundamental principles developed in all the underlying sciences, this contradiction disappears. Many of the fundamental problems in storage and transportation are physiological and pathological while many problems in marketing horticultural crops involve basic principles in economics. We should be closely enough in touch with such studies so that we may be able to bridge the gap between principle and practice.

The growth of helpful cooperation between the different departments of an experiment station and between the departments of different stations is one of the encouraging signs of the present time. Each year a number of formal or informal conferences are now held at which the horticulural research workers from several states with a common group of problems exchange ideas and experiences and plan experiments to avoid unnecessary duplication. The further development of such conferences will result in somewhat greater specialization within the department. Certain problems can be studied more effectively at one station than at another. Other problems require wide-spread duplication but may center around a single research worker as a leader. The station directors in their official meetings are attempting to further this plan of wise specialization. It should be our task to see that our own director has a sympathetic appreciation of horticultural problems and of the particular abilities and limitations of our own department.

It would not do to close this rambling paper without a word about the graduate student and his contribution to research. The graduate student is not immune to the operation of the law of supply and demand. At present we have too many institutions offering work for the Doctor's degree. We need to be much more critical of our own ability to lead this work and much more severe in culling out the men whose possible development will not justify the time and money spent on graduate work beyond the Master's degree. Graduate research would be much helped if all our institutions would remove the requirement of publication of the Doctor's thesis. This would help to take the emphasis from building tables and constructing curves and place it on the development of an enquiring mind.

I close this as I began with a quotation from Chandler, our mentor of more than a decade ago. "It is probable that more often than otherwise when a discovery is made that explains in a fundamental way some response of the tree we shall look, not forward to its application, but backward to find it already in practice, placed there by the results of experience; of field experiments; and of studies of the more superficial responses that the more fundamental study explains."

Plants Which Tolerate Shade Conditions, Hardy in Central New York

By R. W. CURTIS, L. A. MINNS, and DONALD WYMAN, *Cornell University, Ithaca, N. Y.*

ABSTRACT

This will be published as a bulletin by the Cornell University Agricultural Experiment Station.

THE plants listed are all hardy in New York State. They have been divided into four groups according to the soil conditions which they endure or demand, namely, acid, wet, dry and of medium moisture content. General methods of growing azaleas, laurel, rhododendrons, and other plants commonly termed "acid soil plants" are given.

For convenience the woody plants are divided into seven size-groups, depending not so much on their eventual height as on the height at which they are customarily used in landscape plantings. The approximate time of bloom, color of flower and fruit, and the length of time during which the fruit is effective on the plant are also given, together with a short paragraph concerning any special item of interest with which one should be familiar such as autumn color, general outline, growth habits, diseases, or insect troubles.

Since the list of plants is so large it is highly probable that it will serve a much felt need and can be used, at least in part, in many northern localities where the winters are no more severe than in Central New York State.

Vegetable Breeding at the University of California

(Presidential Address)

By H. A. Jones, *University of California, Davis, Calif.*

TONIGHT I will attempt to present a few of the vegetable breeding problems that are of importance in California and something of the program that we now have under way. If plant breeders at other institutions, both in this country and abroad, know of our difficulties, they may be able to give us valuable help. Perhaps, too, some of the work that we are doing in California may assist in answering important questions in other districts.

Vegetable growing in California is a highly specialized and diversified industry. Canning, shipping, and seed production are all important occupations in certain regions of the state. Though the problems confronting the producers of each crop are probably not more complicated than in other states, the magnitude and diversification of the industry in California greatly enlarges our field of investigation.

For a time, when vegetable production in California was in its infancy, crops there were relatively free from attacks of insect pests and plant diseases that have menaced production in many older districts. But since the high concentration of a few crops in rather limited areas has been conducive to pest establishment and spread, growers have had to develop methods of control or face disaster in the production of some important crops. From the beginning we have felt that resistant strains or varieties should be developed whenever possible, since this method is the only known way of securing permanent prevention. The increasing literature on disease resistance in plants indicates that much has already been accomplished in this field. The papers dealing with resistance to insect attack show that here also is a fruitful field for research and one which gives renewed hope for the eventual control of certain highly destructive pests.

Onions

My own efforts have been devoted chiefly to onion breeding. One early request made by seedsmen was to purify the Australian Brown variety, our best storage onion. Since the color of the outer scale and of the flesh is rather variable, the aim has been to combine a chestnut brown scale with lemon yellow flesh. Although a large number of lines possessing these characters have been isolated by inbreeding there has been in every case a considerable loss in vigor. When certain of these inbred lines are crossed, vigor is at once restored; but the problem is to retain this vigor in the succeeding generations. Obviously the same technique cannot be used as with corn, because it is impracticable to emasculate large numbers of flowers. One method that we are now using with this variety

in an attempt to regain and maintain vigor is to mass a large number of lines that have been sufficiently purified by inbreeding and allow them to cross-pollinate promiscuously. All the seed from this massed planting is collected and planted. The large bulbs that appear in this population are attributed to desirable crosses and are saved for increase. Though this method seems to be satisfactory, sufficient data have not as yet been accumulated to show that vigor can be maintained over a number of generations.

Not all onions behave the same as the Australian Brown with respect to loss of vigor. In the Italian varieties, which are very mild in flavor, a number of lines have been inbred for five generations with only slight loss in vigor. These varieties are exceptionally heavy yielders; and the slight loss in yield from inbreeding is more than offset, from the grower's standpoint, by the increased uniformity of color and shape and by the improved keeping quality.

When an inbred line has been sufficiently purified, one must often mass the bulbs in order to obtain a desirable quantity of seed. For a number of years we distributed the different selections miles apart, but we have never been able to secure complete isolation by planting in the open. The amount of crossing in different lots varied from less than one per cent to as high as 50 per cent. This fact compelled us to experiment with the growing of seeds under controlled conditions. In time a method was developed by which satisfactory amounts of seed could be obtained from plants grown under cloth cages. Light weight muslin was used at first, but cheesecloth later proved more satisfactory because it allowed a greater movement of air through the cage and admitted more light. Pollination within the cage is accomplished by flies. These insects must be grown under controlled conditions in order to be free from pollen.

Propagating the flies is not difficult, but a large number must be available for the cages when needed. Waste meat from slaughter houses is placed in troughs in the open, and the adult flies are attracted in large numbers to deposit their eggs. Lungs are an especially good medium, being porous and providing a large feeding area. Within a few days the larvae hatch and begin to feed; when mature, they stop feeding and move about in search of a place to pupate. At this stage they apparently prefer to travel up or downhill; so if the trough is inclined slightly they will go to the ends rather than wander aimlessly about. At the end of the trough they drop into a bucket of fine screened sand, into which they burrow before pupating. After a few days, the pupae are recovered from the sand by screening; then they are washed, dried, and stored at about 3 degrees C, where they may be held for a long period.

By starting to propagate the flies early in the year and then holding the pupae in cold storage, one may accumulate a large supply and hold them in readiness for the pollinating season. When the plants begin to bloom, a small handful of pupae are placed in the

cage every 3 or 4 days. Thus the number of flies inside the cage can be held fairly constant. The flies feed on the nectar and, in migrating from flower to flower and from plant to plant. accomplish thorough pollination. A good set is almost always procured, but the seed yield is often much reduced because the high temperatures within the cage kill the developing seeds.

Flies are also used as pollinating agents in crossing. Their technique is very good, and with their help one can obtain hundreds of crosses where one might secure only a few by hand pollination. For instance, two plants which are to be crossed are set side by side and covered with a small cloth cage; flies are introduced into the cage to do the pollinating. Emasculation is not performed, but the seed from each individual is planted separately. This method of crossing is used only where the hybrids can be identified with certainty, either by the appearance of hybrid vigor or by dominant characters.

In cases where the hybrids cannot be definitely identified, a slightly different system is used. The plants that are to be crossed are set side by side; the female plant is emasculated; an inflorescence of the pollen parent is tied with it; and both are covered with a paper or cloth bag, in which are placed a few flies and pupae. The adult flies and those which soon emerge usually remain active as long as the stigmas of the flowers are receptive. As a rule, a much better set of seed is secured than where pollination is done by hand.

In California, as in many other states, pinkroot (*Phoma terrestris* Hansen) causes considerable loss in the onion bulb and seed crops. During the last eight years a large number of varieties and species have been tested for resistance. The Sweet Spanish type of onion proved more resistant to pinkroot than other varieties. Selections for resistance have been made from susceptible varieties planted on heavily infested soil, and increased resistance is apparently being obtained. Certain varieties and strains that grow during the fall, winter, and early spring, while the weather is cool, are able to escape the attack of the pinkroot organism.

A type of Japanese onion of the species *Allium fistulosum* and known locally as Nebuka was found to be practically immune to pinkroot and was found by Professor A. G. Newhall of Cornell University to be immune to smut. A species cross has been secured between this variety and the Yellow Globe Danvers variety of *Allium cepa*, but to date it has been both self and back-cross sterile. Fortunately the hybrid can be easily propagated vegetatively, and from a single F_1 seed we now have about 100 plants. Hence we have sufficient material with which to experiment in our attempts to bring about fertility.

Downy mildew (*Peronospora schleideni*) is another disease that is very destructive to the onion seed crop at certain times. During the last 8 years the annual losses have ranged from less than one

to about 80 per cent. As breeding for resistance seems to offer the best means of control, we have obtained from India several varieties which are said to be resistant to mildew; but we have not as yet tested these under epidemic conditions.

The control of thrips (*Thrips tabaci*) is another important problem confronting the California onion grower. Spraying or dusting has never given satisfactory control because neither can reach those parts of the plant where the nymphs and adults remain unprotected. The only solution seems to be to develop resistant varieties or strains. An onion which we have called White Persian, obtained from Persia through the Division of Foreign Plant Introduction of the U. S. Department of Agriculture, has proved exceptionally resistant. Though not a good commercial type of onion, it is valuable from the standpoint of breeding. Apparently, the high degree of resistance may be explained by the peculiar growth habit of the plant. In most of our common varieties of onions the leaf blades have a flat side. When the young leaves emerge, their flat surfaces are face to face, pressed closely together. This condition gives the thrips a place of protection from predacious insects and unfavorable environmental conditions. In the White Persian variety the leaf blades are almost circular in cross section, so that there is no sheltered area between the inner leaves. In actual counts made in the field during the summer of 1932, the number of thrips in White Persian was found to average about one-fourth that in other varieties. Crosses have already been made between White Persian and many onions of commercial importance in America. Next year we shall have data which should demonstrate the mode of inheritance of this character.

In certain localities, bolting or premature seeding of onions causes considerable loss. In the upper San Joaquin Valley, seed of the Sweet Spanish variety is sown in the seed bed in September, plants are set in the open field in early winter, and the bulbs are usually mature some time in June. In these fields 50 to 75 per cent of the plants have sometimes bolted. Even in the Delta region of California, where the seed of this variety is sown in the field in January or February, one seldom finds less than 10 per cent bolters. Preliminary work has shown the possibility of isolating lines that are strongly bolting and others that have non-bolting tendencies. Under exactly the same conditions some lines bolt 100 per cent, while others do not bolt at all.

Garlic

Garlic, a close relative of the onion, occupies a considerable acreage in the upper Santa Clara and San Juan valleys of California and is grown in rotation with many vegetable seed crops of those districts. Although garlic is not used in very large quantities by most individuals, the demand is fairly constant, and the total amount consumed is considerable. Two types of garlic are now

being grown: early or Mexican, and late or Italian. During the last few years, the stem nematode has been causing considerable damage to the late garlic crop, whereas the early crop is either resistant or matures in time to escape attack. In an attempt to locate a late garlic that is nematode resistant, varieties to be tested in the infested regions of California are being collected by the Division of Foreign Plant Introduction from the Orient and from the Mediterranean countries.

As garlic is propagated vegetatively, we may have difficulty in securing resistant individuals because of the small number of genotypes from which to select. Under California conditions, garlic is known to bloom very rarely, and all the plants that I have examined have been sterile. Quite possibly there are certain districts where this crop may flower naturally, or certain strains that seed normally, but I have found no reference to them in the literature; and in the collection of foreign varieties secured so far, only bulbs have been received. We shall feel more hopeful of ultimate success with this project when we know and can supply those conditions necessary to induce sexual reproduction.

Cantaloupes

In California, the cantaloupe crop is second in economic importance only to lettuce. When allowed to develop normally, the fruit reaches perfection under the clear skies, high temperatures, low humidity, and irrigated conditions of the Imperial Valley. Since 1925, however, yields have been somewhat reduced and the edible quality has been lowered by attacks of powdery mildew (*Erysiphe cichoracearum*). This disease has become permanently established in the Imperial Valley, where attempts to control it by spraying and dusting have not been satisfactory.

From the first appearance of this disease the development of resistance seemed to offer the most satisfactory method of control. Accordingly, melon varieties were collected from all parts of the world and were tested under epidemic conditions in the Imperial Valley. In 1928 a mixed lot of seed from India produced numerous plants which were practically free from mildew; but the melons from these plants were of no commercial value because of their low sugar content, unpleasant flavor, and inferior shipping quality. It has been possible however, to combine the resistance of the Hindu melons with the eating and shipping qualities of our standard varieties. By repeated crossing with commercial cantaloupes and continuous selection among the progenies under epidemic conditions, desirable commercial types resistant to mildew have been developed. Though the mode of inheritance of the factor for resistance has not been definitely determined, it appears to be a simple Mendelian dominant. Under the most favorable conditions for infection, dominance may not be complete, and the plant heterozygous for the factor may be slightly infected.

In 1932 over 1000 pounds of resistant seed was distributed to seedsmen and growers in the Imperial Valley. By 1934, sufficient seed should be available to plant the entire cantaloupe acreage of that region with resistant strains. Progress in the development of resistant varieties has been rapid because three generations of cantaloupes can be grown each year. A fall crop in the Imperial Valley matures in time to plant a spring crop there, which matures in time to plant a summer crop at Davis in the Sacramento Valley, which in turn matures early enough to plant the fall crop in the Imperial Valley.

Other types of melons of considerable commercial importance in the Imperial Valley are Honey Dew, Honey Ball, and Casaba, which are all susceptible to mildew. Although considerable progress has also been made in developing resistant strains of these varieties, none of the selections are as yet sufficiently pure for introduction to the trade. The resistance factor incorporated in Honey Dew and Honey Ball is from a white Hindu melon, a different parent than that used in the development of the resistant cantaloupe. The melon breeding program is in cooperation with the United States Department of Agriculture and the Western Growers' Protective Association.

Powdery mildew of cucumbers is prevalent in the pickle-producing areas of the San Francisco Bay region and the districts of southern California that ship slicing cucumbers. In a search for resistant types, preliminary trials have shown that certain varieties obtained from India possess marked resistance.

Celery

Another vegetable that presents many problems for the breeder is celery. The growing of this crop is localized in the delta region of central California and near Venice and Chula Vista in southern California. With celery as with many vegetable crops, the troubles one encounters vary somewhat according to the district in which it is grown. In nearly all sections, pithiness accounts for considerable loss. Almost certainly there are two types of pithiness, one being a breakdown of the parenchyma tissue in the petiole that accompanies aging, the other being present from the young seedling stage. This latter type of pithiness has been found to be caused by a single gene that is dominant to the recessive condition "solid petiole." Because it is dominant, a few plants occurring in a seed field are a ready source of contamination. It may be eliminated from the seed stocks by cutting the petioles of the mother plants and discarding those that are pithy so they will not be set in the field.

Considerable damage is also done by plants bolting to seed instead of forming a rosette. Though these losses occur to some extent in all districts, they are most severe in those sections of southern California where the crop is set in the field during the winter.

Sufficient work has not yet been done to determine the mode of inheritance of this character; but lines have been isolated that bolt 100 per cent, while still others are 100 per cent non-bolting under the same environmental conditions. The results seem to indicate that the bolting habit in celery is genetic in nature and is probably controlled by several factors.

Carrots

The carrot crop in California has become increasingly important during the last few years. Very little breeding work has been done on this crop, and reports as to self-fertility and sterility are rather conflicting. For the last three years we have been trying various methods to secure seeds from single plants isolated under cloth cages. This year we decided to introduce flies into the cages as pollinating agents; and in all such cases, we secured a satisfactory set of seed. No seed was secured in the check cages.

The data on the effect of inbreeding are yet very meager; but in two varieties, Danvers Half Long and Coreless Half Long, we find an appreciable loss of vigor after one generation of inbreeding.

An interesting problem now confronting the carrot grower is color of root. In many instances the fall and winter crop of carrots, which mature during cool weather, are light yellow in color. At present we have several lines of Danvers Half Long in which all the roots are light yellow, and other sister lines in which all roots are dark yellow. It is a little premature to state that this is wholly a genetic problem, but results such as these indicate that heredity is of considerable importance.

Tomato

The tomato in California is important both as a canning and as a shipping crop. Though many problems need solution, I should like to mention one point at this time, namely, the adaptation of varieties. It is becoming more and more evident that varieties are not equally well adapted to all districts. The tomato seems to be more delicately adjusted to its environment than many other crop plants. For instance, the Break O'Day variety which has been reported upon so favorably in the East has, with us, proved to be almost worthless. The same is true of several other varieties that are especially important in the East. The performance in the East of several important Western varieties, such as the Santa Clara Canner and the San Jose Canner, is not at all satisfactory. In California a strain of the Santa Clara Canner may do well in one valley, while in another valley, less than a hundred miles away, some other strain may be more satisfactory. This adaptation of different strains has been so apparent that special breeding work on this crop seems to be necessary in each of the different districts where the crop is important. This method is bound to multiply strains and varieties, but it seems to be the only satisfactory way

of securing the best strain for each locality. Breeding for resistance to curly top, our most serious tomato disease, has been in progress for a number of years at the Riverside station. Although dwarf varieties have been shown to be slightly resistant, there have not as yet been developed standard types that are resistant under conditions of heavy leafhopper infestation.

Cauliflower and Broccoli

The cauliflower and broccoli industry of California is located in districts along the coast, where the climate is tempered by the Pacific Ocean. Most of the crop is shipped during the late fall, winter, and early spring.

Our work at the University has departed somewhat from the traditional lines of plant breeding in the improvement of this crop. We have found many plants to be self-incompatible; that is, they do not set seed when the open flower is pollinated with its own pollen. Flowers of these self-incompatible lines will, however, set seed when their own pollen is applied in the bud stage. A considerable number of self-incompatible lines are carried along and are crossed with one another to secure all possible combinations, and the only lines maintained are those which produce hybrids possessing desired commercial characteristics. Large quantities of seed can be produced by planting self-incompatible lines side by side. Although this system has given excellent results experimentally, it has still to be tested on a commercial scale. By this method a breeder who develops outstanding hybrids may be rewarded for his efforts by being able to keep the parent lines in his own possession. Under present methods the commercial vegetable breeder is seldom able to obtain profit from his work because, improved varieties, when once introduced become the common property of all. This same method of improvement can also be practiced with varieties of cabbage.

A somewhat similar system, whereby the breeder can keep control of his parent stocks, is also possible with the onion. Lines have been isolated that are male sterile. When such a line is caged to prevent cross pollination, seed is not set, but large quantities of bulblets are formed in the heads. When on the other hand, it is allowed to cross pollinate with lines having good pollen, an abundance of seed is set. The male sterile line is carried along by vegetative propagation and can be kept in the control of the breeder.

Watermelons

The main areas of watermelon production in California are in the San Joaquin and Imperial valleys. Although both these regions grow the Klondike variety, they demand slightly different types. Imperial Valley growers prefer a small melon averaging from 16 to 20 pounds, since their product is marketed in early spring when prices are usually high. Growers farther north, however, favor a

larger melon, averaging from 22 to 26 pounds, since their crop is marketed at a time when prices are lower and when a large melon finds more ready sale than a small one. Watermelon breeding has been under way in California since 1923. The Klondike variety has been inbred, until at present we are able to provide growers and seedsmen with whatever types they desire. Inbreeding has served to isolate strains differing in fruit size, shape, and color; rind thickness and toughness; flesh color, texture, sugar content, and solidity; seed coat color, and seed size; and melon yield. We have distributed to seed companies lines that are as nearly perfect as the trade could desire and which, although inbred for seven generations, yield as well as commercial stocks or even higher. Loss of vigor is not a factor in watermelon breeding; hence desirable types are relatively easy to isolate and maintain.

Though we are now able to satisfy the trade with desirable Klondike strains, the time is not far distant when these strains will be absolutely worthless, for they are extremely susceptible to watermelon wilt, (*Fusarium niveum*), a disease which persists indefinitely in infested soil. Thousands of acres in California are now wilt sick. The wilt-resistant varieties, Pride of Muscatine, Iowa King, and Iowa Belle, though resistant wherever tested in California, are of undesirable market type; hence they cannot be used even where wilt is a factor in this state. Since 1926, efforts have been made to isolate a wilt-resistant Klondike type; but no progress was made until the Klondike was crossed with the three resistant varieties previously mentioned. Though resistance is inherited as a recessive character, we now have lines which, in 1932, were 70 per cent resistant, with many plants producing melons of extremely high quality.

Asparagus

One of the most highly specialized truck crops in California is asparagus. Although the production areas are somewhat scattered, the main region for both the shipping and canning industry is located in the delta lands of the Sacramento and San Joaquin rivers. Our program of research with this crop touches many phases of production, but the breeding work is designed mainly to assist the canning industry. Spoilage in canned asparagus is said to be directly proportional to the amount of soil carried into the can under the scales on the spears. This difficulty is not eliminated by care used in washing, but it may be lessened to a considerable extent by securing through breeding a type in which the leaf scale is small and tightly pressed against the spear. At our asparagus station in the delta region of California, a rather extensive breeding program is under way. An effort is being made to develop a variety with a milder flavor, a minimum of waste, and a greater uniformity in size, shape, and color than our present varieties.

Flower Crops

The production of flower seeds is another important industry in California. Despite the number of important breeding problems in this field, very little has been done so far. It is almost a virgin territory, and a fascinating one for the plant breeder. To cite just one of the problems; the snapdragon seed growers in the West have been requesting the development of strains resistant to rust (*Puccina antirrhini*). The seed is grown along the coast, where the conditions are ideal for rust infection; and the plants are generally killed before the seed crop is mature. The result is a very much reduced seed yield. Several rust resistant lines have already been isolated, but these do not as yet possess the desirable commercial flower characters. The development of desirable flower types is now in progress, and the results so far achieved indicate that desirable resistant types will soon be available.

For much of the breeding work with vegetable crops the securing of varieties that have been cultivated from prehistoric times, in isolated districts where they have not been contaminated by outside sources, is of considerable importance. Most of the varieties that are being grown in these distant regions are of little commercial value, but they often do contain single outstanding characters that are wanting in our own cultivated varieties. In order to secure these primitive varieties one must communicate with the most remote parts of the world, and we have found that the best medium is the Division of Foreign Plant Introduction of the U. S. Department of Agriculture. I know of no other agency so well equipped to make the proper contacts and to give assistance in the type of program that we have undertaken.

In conclusion, may I hope for an increasing freedom in the discussion of our problems, a more liberal exchange of ideas and materials, and a closer cooperation between institutions as well as individuals. The opportunities for service in vegetable breeding are far-reaching; let us make the most of them.

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